DETROIT OFFICE
1215 WOODWARD AVENUE

CHICAGO OFFICE
68 EAST TWELFTH STREET

LEAF SPRINGS

Their Characteristics

and

Methods of Specification

A HAND-BOOK OF USEFUL INFORMATION RELATING TO AUTOMOBILE LEAF SPRINGS, THEIR MANUFACTURE, METHODS OF SPECIFICATION, DETAILS AND CHARACTERISTICS, TOGETHER WITH A GLOSSARY OF TERMS USED IN THE ART

EDITED BY
DAVID LANDAU
CONSULTING ENGINEER SPRING DEPARTMENT

SHELDON AXLE COMPANY
SPRING ENGINEERING DEPARTMENT
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PREFACE

The subject of automobile leaf springs has been discussed at various times in the technical press, and before engineering societies, but never have the more patent facts dealing with their details and modes of specification been made an issue.

There has been a lack of practical data to assist the designing engineer in a better understanding of this subject. He has been compelled to resort to lengthy correspondence with the spring maker and this has resulted, with few exceptions, to mutual misunderstanding. The fault lies with the spring maker. He has not stated his case.

It is with the desire that the engineer be given all the information necessary to a complete understanding of the subject of leaf spring specifications, that we have attempted here, for the first time, to give it the treatment that it deserves.

The object of the work is to enlighten the engineer as well as the user, by elementary and logical discussion of the details of construction and the proper form of specification as applied to leaf springs used on power-propelled vehicles.

Impartial treatment has been the aim throughout, and to attain this end, general statements are made. Whenever it was thought that a principle or statement could be made clearer it is supplemented by line cuts, and typical examples taken from practice. Criticisms have been made in their proper places and reasons given therefor. The treatment is thus impartial and, in this respect, the present work fulfills the mission of a text-book. This will enable the subject matter to be applied, as was intended, to the study of any maker's product.

Owing to the rapid growth of the leaf spring industry in the last few years, many new terms have been introduced and the meaning of several of the older ones changed slightly. A glossary of the more important of these has, therefore, been added at the end of the book. This should assist the reader in the more complete understanding of the spring maker's correspondence. The glossary is new and is published for the first time.

Every endeavor has been made to shed light on some of the obscure problems in this branch of engineering and it is the hope that future specifications will bear evidence of this work, and the art, as a whole, may be benefited thereby.

While this book was in course of preparation several of our friends asked us to include a brief description of our plants, organization, and processes, and in accordance with their wish we have included such a description at the end of the work.

The Editor cannot too strongly express his appreciation and thanks to Mr. William H. Son, Vice-President and General Manager of the Sheldon Axle Company, who has made this work possible.

As a practical investigator he has done much during the past quarter of a century to improve leaf springs. He was the first to introduce the test data specification sheets for engineers, and inaugurate the first spring engineerng staff in this country.

Acknowledgment is here made to all those who have assisted in the preparation of this text and in particular to R. A. Schaaf and John B. Kaier of the Spring Engineering Department.

The Editor has made every effort to have this work free from errors and solicits suggestions or criticisms tending toward the improvement of subsequent editions.

SHELDON AXLE COMPANY
Spring Engineering Department

David Landau
Consulting Engineer

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PART I

HISTORICAL

It is not definitely known who invented leaf or plate springs, but history seems to point that shortly after the year 1750 these contrivances were popularized by vehicle makers in England, and shortly afterward in France and Germany. Their high cost at this time prevented their general adoption and we are probably right in assuming with Mr. William Bridges Adams, "That wealthy men led the way by having coaches built on springs or altering their vehicles."

In the year 1768 Dr. R. Lovell Edgworth succeeded in demonstrating the advantages possessed by vehicles that were sprung, and he was awarded three gold medals by the Society of English Arts and Manufacturers.

In the now well known work, "A Treatise on Carriages and Harness," by William Felton, published in London in 1790, we are informed that springs were marketed during that time, thus showing that this specialized industry had been started.

Obadiah Elliott, a noted English carriage builder of Lambeth, obtained a patent in 1804 for a means of suspending vehicles on elliptic springs. The Society of Arts awarded him their gold medal and the popularity of his product, and his success in general, were doubtless prompted by this official recognition of merit.

The mechanics of plate springs were expounded by Clark (1855), although the laws governing their deflection were incorrectly stated. Later, and in our own day, Reuleaux gave a more nearly correct expression for deflection and stress of these members. In 1894 G. R. Henderson corrected the Reuleaux formula for deflections, while Professor John Perry called attention to the internal stresses produced by "nipping."

Uniform thickness of leaf spring steel is of immense importance. Close tolerances in this direction were not to be had when materials were hand-made, except at a great expense. The process of rolling steel, first introduced by Cort, overcame many of these objections, but even the rolling mill has undergone another change.

To Wedgwood, the scientific English potter, we are indebted for the Pyrometer. The original instrument has passed through many changes and has been superseded by the improved apparatus of LeChatelier, Sir William Siemens and others. The later types of these instruments, through their increased sensitiveness, have made possible increased production, coupled with uniformity.

Since the late Dr. Charles P. Dudley, of the Pennsylvania Railroad, began his first investigation on spring steels, metallurgy has been able to give to the world a series of most valuable spring steel alloys. Perhaps the greatest strides have been made in the selective processes of heat treatments.

The introduction of the electric furnace for the manufacture of steel by Stasassano, Kjellin, Heroult, Girod, and Hiorth, and the work on the micro-structure of steels first introduced by Dr. Sorby, of Sheffield, and improved upon by Martens, Roberts-Austen, Stead, Ewing & Rosenhain, Guillet, Sauveur and others, is just bringing us into a field of improvements whose latent possibilities cannot be predicted.

The most recent innovation has been the introduction of the Spring Endurance Testing Machine, probably first suggested by the Editor in 1908 and applied in the following year. This machine furnishes us with the knowledge of the durability of a spring, reproducing in a few hours or days an event otherwise occupying many years.

Numerous detail improvements, both in the leaf springs and the machinery used in their manufacture, have been made, but space forbids their further mention.

PART II

LEAF SPRINGS

A WORD OF INTRODUCTION

Automobile builders are often considerably at a loss as to the best method of making known their wants to the spring manufacturer. Why should this be so? Is the subject difficult to comprehend, requiring in every case the presence of an expert? A well designed and constructed spring is worthy of the efforts of the most skilled mechanic and the most competent engineer. New problems are constantly appearing, even to those who have made springs a life study. But we are now discussing only the writing of a spring specification. By spring specification we mean a comprehensive statement by the car builder of his requirements as to spring suspension. Is that an involved matter? We think not, once we have looked it over.

A spring is a flexible body having no one fixed set of dimensions. It may have various groups or sets of dimensions, one differing from the other, according to the work it is doing. To design his product well the spring manufacturer must know definitely what load the spring is to carry. These two conditions, namely, varying dimensions and knowledge of load will, we believe, be found accountable for almost every difficulty experienced in writing spring specifications.

The following pages have been written with one object:—to present such facts as the car builder wishes to have when laying out his springs, and to give them in such concise form as will enable him to avoid correspondence. Many of the matters considered will be found elementary and our more experienced friends may therefore find us tiresome. We ask them to bear in mind that we are writing for all classes of spring users, the novice as well as the veteran, and we believe that before the final page is reached even the more experienced will find some items of value.

PART III

LEAF SPRING DETAILS

Details We will have occasion, very often, to mention various spring details. To avoid misinterpretation it may be well to examine a few of these and become acquainted with the spring maker's names for them. The car builder will then also be better able to interpret the test records and other spring literature he receives.

Half Elliptic Springs Figure 1 shows a "half elliptic," or as it is frequently called a "semi-elliptic" spring. It is the basic or elementary unit from which all other types of plate springs are built up. When its curvature is uniform from end to end, as shown in Figure 1, it is said to have a "true

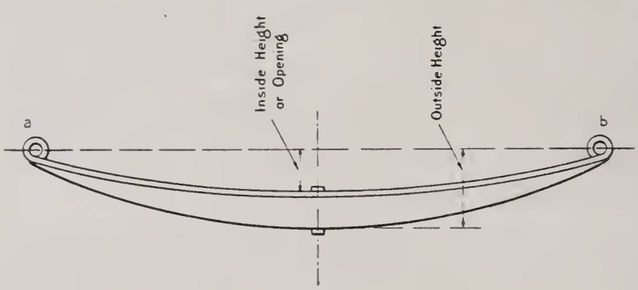


Fig. 1

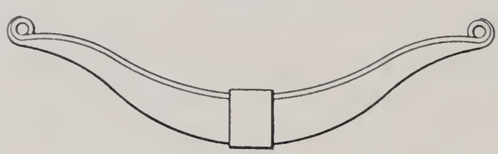


Fig. 2

True Sweep Double Sweep sweep" shape. When its curvature is reversed, as in Figure 2, it is said to have a "double sweep." Double sweep springs are used only under heavy trucks, practically never in pleasure cars. They may, perhaps, possess more graceful lines than a true sweep spring. The change in curvature also produces greater friction between the leaves than in a true sweep shape, which would be an advantage in dampening the oscillations of a car after mounting an obstruction in the road. On the other hand, we are inclined to believe that these springs will not retain their shape as well as a true sweep spring. This, together with the fact that they weigh a little more than a true sweep spring of the same length, may neutralize any improvements in their riding qualities. The question of true sweep versus double sweep is much in dispute and will bear close investigation. Let us say, however, that the double sweep should be avoided as much as possible.

Eyes

In the above figures "a" and "b" are called the "eyes" of the spring. Considerable wear is apt to take place in these during service, due partly to lack of oil and difficulty of access, but perhaps in a greater measure to the abrasion of grit and dust always so difficult to exclude. To allow

Bushings

for wear the eyes should be bushed. Bushings may be of phosphor bronze, Tobin bronze or steel, preferable in the order named. When bronze bushings are used, case hardened and ground shackle bolts should be used in combina-

Reaming

tion with them. Whether bushed or not bushed, it is advisable to ream all eyes to size.

Eyes Turned "Up" or "Down"

Relative Strength and Advantages

The eyes in Figures 1 and 2 are "turned up." This is the strongest and most logical construction, for in it the leaf immediately below the eye is brought well toward the end so as to reinforce the eye. It is strong also because the thrust of the bolt falls on the leaf itself, the eye doing little more than keep the bolt in place. Eyes may be "turned down" as in Figure 3. It may happen, in planning a spring, that

Fig. 3

the centers of the eyes fall very nearly on a line drawn horizontally through the highest point on the top leaf, as in Figure 4.

Fig. 4

Fig. 5

The spring will then have a downward bend at each end, which gives it a weak and awkward appearance. In such cases matters can be improved by turning the eyes down, the upper leaf then having a slight upward curvature, see Figure 5. When eyes are turned down the next leaf cannot be brought up underneath them as a reinforcement. It should also be noted that in this construction the thrust of the bolt tends to open up the eye. For the reasons just mentioned it is advisable to use this type of eye only in springs carrying small loads. Eyes may also be

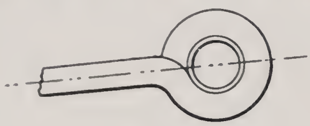


Fig. 6

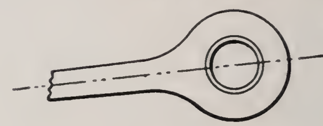


Fig. 7

Berlin Eye

Forged Eye

made as shown in Figure 6. These are known as "Berlin" eyes, and may be turned up or down. Or the eye may be forged solid as shown in Figure 7. This last construction is expensive, but is excellent when properly made. They are called "solid" eyes or "forged" eyes.

Master Leaf

Long Plate

Short Plate

Spring Seat

The uppermost, or top leaf, which carries the eyes, is called the "master leaf," or "main leaf." The leaf immediately below is termed the "long plate." The lowest leaf is called the "short plate." That part of the axle on which the spring rests is variously called the "spring seat," "spring perch," or "spring chair." The term "spring seat" is also applied by the spring maker to that portion of the short plate which rests upon the axle.

Importance of Short Plate Length

A little thought will make it clear that the length of the short plate is a most important matter. Its length governs the length of all the other leaves. It influences not only the amount of material which goes into the spring, but its entire action and manner of carrying any given load. To the car builder it is not an essential dimension. To have it a trifle longer or shorter is not a vital matter to him; and, as it plays such an important part in the design of the spring, it is in all cases left to the spring manufacturer for determination.

Center Bolt Diameters

The bolt holding the leaves together is called the "center bolt." It can be furnished with square, hexagon, cone or fillister head. Figure 8 shows details of a 5/16″ center bolt very extensively used. Springs

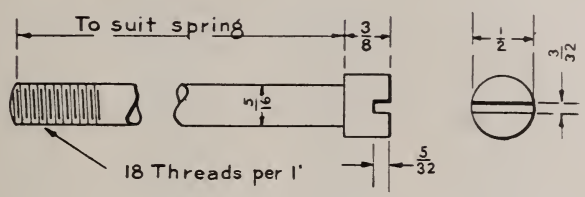


FIG. 8

$1\frac{3}{4}$″, 2″ and $2\frac{1}{4}$″ in width, unless having a very large number of leaves, are assembled with 5/16″ center bolts. $2\frac{1}{2}$″ and 3″ springs have $\frac{3}{8}$″ bolts and $3\frac{1}{2}$″ springs have them 7/16″ in diameter.

Eye Bolt Diameters

The diameter of spring bolts has been tentatively settled by the Spring Division, Standards Committee, of the Society of Automobile Engineers at this writing. The diameter of the bolt has been given in terms of the spring width. The formula proposed by this Committee is $D = \frac{W}{4}$ but in our estimation better results are sure to be obtained by changing the formula to read $D = \frac{5\,W}{16}$ where D=the diameter of the bolt in inches and W the width of plates in inches. The bearing pressures must not be exceeded and experience shows that 600 to 800 pounds per square inch projected area on bolts of this description are safe. We can then reduce this formula in terms of the bearing pressure. This gives us the equation:

$$D = \frac{Q \times .000835}{W} \text{ to } D = \frac{Q \times .000625}{W}$$

where Q = the load on each spring and W the width of spring.

Special Bead or Nib

Instead of having a center bolt, springs may be assembled with a "special bead" at the center, also called a "nib." The relative advantages of center bolt and nib form an open question. Many arguments are advanced for both constructions; at present the nib is comparatively little used.

Location of Center Bolt

A center bolt may actually be placed at the center of a spring or be located forward or to the rear of that point. One reason, among others, for placing the center bolt forward of the center in front springs, is to increase the wheel base. This is perfectly proper but should be resorted to with great care, for when the off-center distance is large it becomes difficult to maintain a level spring seat, and it gives the spring a bad appearance.

Off-Center Springs

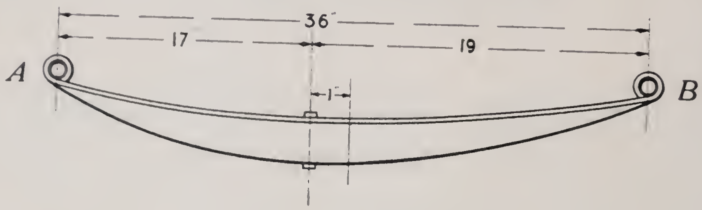


Fig. 9

In Figure 9 we have a 36″ spring in which the center bolt has been placed 1″ forward of the center. The distance from A to the bolt will then be 17″ and from the bolt to B 19″. To find the off-center distance we merely get the difference between the two "half" lengths and divide by 2. Or, conversely, if the off-center distance is specified we can find the two partial lengths by adding it to the actual half length in one case and subtracting it therefrom in the other.

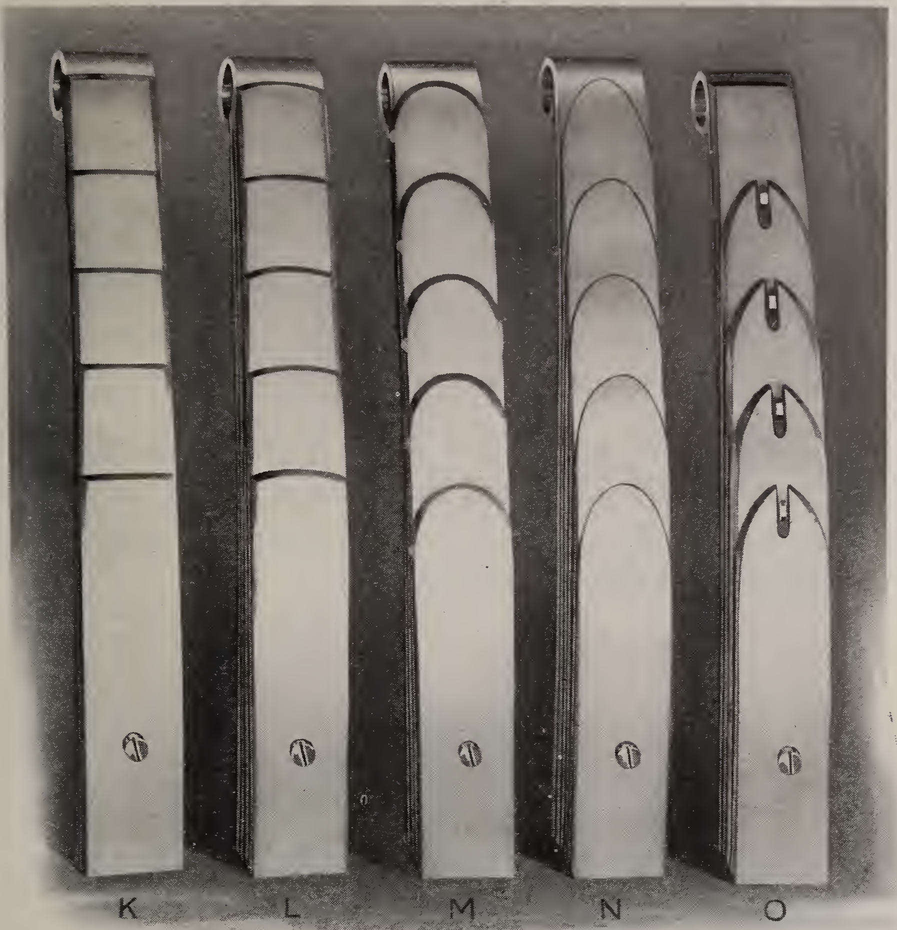
Leaf Points

Tapering

All leaves of a spring, except the master leaf, are usually tapered at each end. The operation of producing this taper is variously called "rolling," "drawing," and "pointing." The ends of the leaf are accordingly called "points." Points are shaped in various ways, the more common of which are shown in Figure 10. The shape of points is largely a matter of appearance and taste. The round point is the most common, being used on all carbon spring work. Ovai points are used in truck springs of alloy steel, French points in pleasure car springs of alloy steel.

Long Plate Full Thick

In heavy truck springs, to stiffen the spring, the "long plate" may not be tapered but be cut off "full thick." In that case the third leaf may be carried to the end and tapered, the remaining leaves being spaced from there on, Figure 11. A modification of this construc-



K—Square
L—Special round (oval)
M—Round
N—Egg shaped
O—South American slot and bead

Fig. 10—Points

Fig. 11

Fig. 12

tion, used to strengthen the eye, is shown in Figure 12. The long plate is here wrapped around the eye and is known as a "wrapper."

Wrapper

In service the leaves of a spring tend to move transversely, or from side to side. There are a number of ways in which they can be kept in proper alinement and the lateral motion just mentioned prevented. The sim-

Alinement of Leaves

Saw and Bead plest method is to "saw and bead" all the leaves. A small projection or "bead" on the lower leaf work-

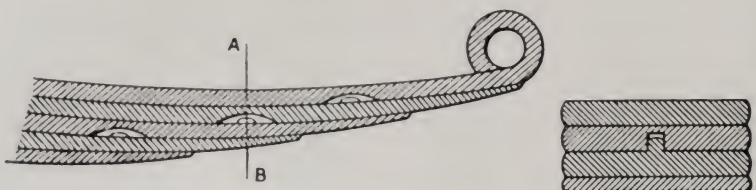
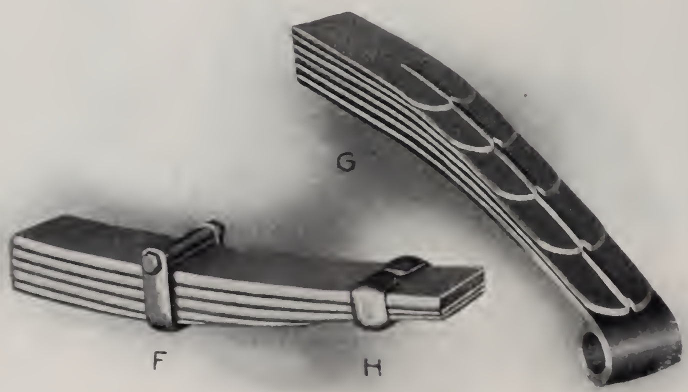


Fig. 13

ing in a narrow slot or "saw" in the leaf above, see Figure 13. Metal is removed from one leaf and metal distorted in the other when securing the leaves in this way. It can, therefore, hardly be recommended as the best practice.



F—Special clip with tube H—Clinch clip G—Ribbed spring

Fig. 14

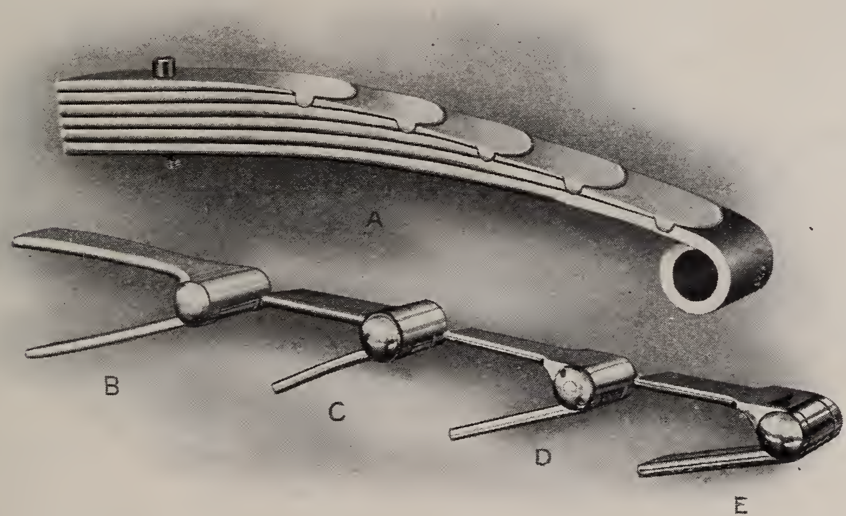
Another means of securing the leaves in alinement is to "rib" them, see Figure 14. The rib is supposed by many to extend the whole length of each leaf, and they do in some foreign makes of springs. In reality it is made only of such length as to extend a short distance beneath the next leaf. It cannot be denied that a rib improves the appearance of a spring, apparently strengthening it. The actual improvement of strength and riding qualities are very small, in fact are negligible. On heavy truck

Ribbing

Strength Only Apparent

Stress Changes Due to Ribs

springs having a large number of leaves, each rib is short, it may not extend much beyond the tapered portion of the leaf, and consequently has little effect on the leaf action. When, on the other hand, a rib is applied to a spring with but few leaves, its length becomes proportionately greater, extending well in toward the center of the spring. Its effect then bears close examination, for it is there subjected to the stress acting along the entire length of the leaf. It is a well-known fact that, all other things being equal, a thin leaf can be bent a greater number of times without breaking than a thick leaf. A rib, by thowing metal up above the normal surface of the leaf, makes that leaf act as though it had been increased in thickness; and, as such, that leaf is more liable to break than if it had not been ribbed. In technical language, the stress in the leaf is increased because the most remote fibre is further from the neutral axis.



A—Lipped spring
B—Button head
C—Berlin head
D—Closed open head
E—Open head

Fig. 15

One of the best means of preventing lateral motion is to fit the end of each leaf with small side projections extending upward and close to the leaf above. These are called "lips," see Figure 15. They have the advantage of placing the holding mechanism at the end of the leaf,

Lips

where it is most needed. Lips are not welded on, but forged from the leaf itself by spreading its end before pointing. They are consequently an integral part of it. Moreover, in making them it is not necessary to remove metal from the center portions of the leaf, and thus add a liability to breakage.

Lips the Strongest Construction

When a car wheel mounts an obstruction in the road the spring immediately above it is suddenly deflected. As the spring relieves itself the car is thrown upward. And as the spring forms a more or less rigid connection between the axle and frame the upward movement of the frame carries the axle and wheels up with it. As commonly constructed, a spring is made to resist only downward pressure, the whole force of any upward pressure falling on the master leaf. The upward motion of the frame after rebound therefore tends to bend the master leaf upward. To throw the whole rebound pressure upon that leaf only would soon result in breaking it. In order that the leaves of the spring may resist the rebound *as a whole* they are bound together by "clips," see Figure 14.

Clips, Advantages of, in Rebound

Clinch Clips

Clips are of two kinds, as shown. Clinch clips are used only where but a few leaves are to be held together, as at the ends of a spring. When the combined thickness of the leaves to be clamped is large, special clips should in all cases be used. They may be fitted with a sleeve or tube slipped over the bolt to prevent binding or locking the leaves together. Ribbed leaves, for obvious reasons, are not usually fitted with clips.

Bolted Clips

The front end of rear springs may be used to transmit the driving effort from the axle. The master leaf of the spring is the only leaf connecting the axle to the car and will transmit the entire driving effort itself unless properly clamped to the shorter leaves by means of clips. Unless such master leaves are secured by clips buckling and breakage will surely result. *The spring manufacturer should therefore always be advised of the fact when driving through the rear springs* so that he can make the necessary provisions as to clips and other details.

Clips Essential When Driving Effort is Taken by Spring

PART IV

EXAMINATION OF MATERIALS

A few remarks as to the kinds of materials used in plate springs are here in order. Wrought iron, as we know it, should consist of the element iron in its purity, with no other metal added and with the impurities incidental to manufacture reduced to a minimum. It is a comparatively soft and plastic metal. It canont be easily hardened. When bent or distorted considerably from its original form it retains its new shape. No physical treatment or heat treatment will alter this latter characteristic materially; the iron still remains an almost inelastic substance.

Properties of Wrought Iron

Early in the history of metallurgy it was discovered that if a small percentage of the element carbon be intimately combined with iron, the characteristics of that metal undergo a remarkable change and improvement. The new metal, still much like the old in appearance, can now, by suitable heat treatment, be hardened. Should a piece of it, after such hardening, be bent from its original shape, it will resist the pressure applied and snap back into the original shape. In short, it is no longer a plastic material, but an elastic material. We see then that, broadly speaking, steel can be regarded as iron which has been converted into an elastic material by the addition of carbon.

Steel is Wrought Iron Containing a Larger Percentage of Carbon

Steels contain various percentages of carbon, depending on the purposes for which they are intended. When used for springs approximately one per cent. of carbon has been found best. In the early eighties the Pennsylvania Railroad Company made long and costly investigations into the merits of the various carbon steels then on the market. These investigations were conducted by their chief chemist, the late Dr. Charles P. Dudley. It was found that steels having carbon ranging from .95

Pennsylvania R. R. Co.'s Investigation of Spring Steels

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to 1.10%, or practically one per cent., were the most efficient from all points of view. The spring steel specification then prepared has since become standard for vehicle springs also. It is universally recommended in all branches of the spring industry, having withstood the hardest service. As a simple carbon steel it has so far had no rival, and may be looked upon as the acme in that class of material. It is the only material used in "Dragon Brand" springs.

Spring Steel Contains 1% Carbon

"Dragon Brand"

The advent of the motor car forced springs into a service more severe and exacting than any they had been called upon to perform during the past. The speed and weight of the new vehicle produced shocks and deflections unknown before. There has consequently arisen in recent years a need for a steel even better than the carbon stock described above.

Carbon Steel No Longer Adequate

It has been found that a carbon steel can be greatly improved by the addition of very small percentages of the heretofore less used elements, such as silicon, manganese, chromium, nickel, vanadium, tungsten, etc. Steels containing these elements singly or in various combinations, in addition to carbon, are called "Alloy" steels.

Alloy Steels

It is not our purpose here to extol the virtues of any one alloy steel. All have their inherent advantages and purposes for which they are admirably suited, while many undoubtedly have bad points. New elements and combinations are constantly appearing. In the course of time, by the natural processes of selection, the best alloy will survive, and, as in the case of the carbon steels, will be looked upon as standard.

Standards for Spring Steels

It is often supposed that an alloy steel will, in itself, improve the riding qualities of a spring. It is imagined, for instance, that to replace a poor riding carbon spring by an alloy spring of the same dimensions throughout would result in a marked betterment of the riding qualities. This is an error which we most emphatically contradict. The new spring will ride exactly the same as the old one. It will, however, possess

Alloy Steels Do Not Change Riding Qualities

Alloy Steels Increase Length of Life

one vast advantage in that its "life" will have been remarkably lengthened. The alloy is a hardier material, better able than the plain carbon spring to resist repeated deflection. In everyday language, the spring "will last longer." This is the only superiority which can be claimed for an alloy steel legitimately. The increased cost of the better material is returned in greater *endurance* and greater *resistance to fatigue.*

The fact that an alloy spring will ride the same as a carbon spring of the same dimensions will be better appreciated by the

Effect of Modulus of Elasticity

engineer, when we tell him that all steels have practically the same modulus of elasticity. Plainly stated, the relation between any load and its corresponding deflection is the same for all spring steels. This relation being constant, one spring must ride the same as another if they are of the same dimensions throughout.

Thickness of Spring Steel

In the vehicle spring industry the thickness of the leaf is measured by a gauge known as Stubbs or Birmingham gauge. Its value in decimals of an inch is as follows:

Gauge	Decimal Equivalent	Difference between the Gauges
3/8	.375″	
		.035″
0	.340″	
		.040″
1	.300″	
		.016″
2	.284″	
		.025″
3	.259″	
		.021″
4	.238″	
		.018″
5	.220″	
		.017″
6	.203″	

It will be noticed that three-eighths is listed instead of 00 (.38), as there is little difference between the two thicknesses. Three-eighths is the greatest thickness carried in a carbon stock.

3/8 the Greatest Thickness

Greater thicknesses than this may be used, but only with the greatest care or the stresses produced may exceed the elastic limit of the material. Consequently, they are little used and are not carried in stock. It is unfortunate that the difference between successive gauge numbers are so irregular. They seem to have been determined more by chance than according to any fixed law.

Advantages of Inch Thicknesses

In order to eliminate the disadvantages resulting from irregularities of the Stubbs gauge numbers, the Sheldon Axle Company has inaugurated the practice of having its alloy steels rolled in thicknesses measured by fractions of an inch. The steps between successive thicknesses are then uniform, and, as they differ one from the other by only 1/32″, better grading of the leaves can be had, resulting in a more uniform and efficient distribution of the material in the spring.

PART V

PROPER COMPARISONS OF LEAF SPRINGS

How shall we compare one spring with another? What are the indexes of excellence to be looked for in this part of a car?

Easy Riding

First in importaince comes comfort and the ease of riding. Judge by this quality first of all. If a spring rides poorly it is not fulfilling its mission and should be rejected, but we ask you not to reject it before consulting the man who made it. In determining its dimensions he very often labors in the dark because of incomplete information. He can hardly be expected to allow beforehand for all those small details which contribute so materially to a proper suspension. Let him see the car, give him every opportunity to inspect, to measure, to weigh, to test, and if he then fails to produce good riding, go elsewhere for your springs, but not until then.

Car Inspection by Spring Constuctors

Endurance

Second in importance comes the length of life. The spring must last and endure in service as well as ride properly. How can we make sure that a spring will have a reasonable length of life and that it will resist wear and its consequent destruction?

Breakage Produced by Repeated Bending

The leaves of a spring are never stationary when in service. They are constantly being bent back and forth, and we know, without further explanation, that no bar of metal can withstand indefinitely such repeated bending. If subjected to such treatment it will finally yield to fatigue and break.

Steel is Stretched When Under Load

When we bend a bar or plate of metal we stretch some and compress others of its fibres, these fibres again resuming their original length when the bar is released into its free state. A spring when placed in position on a car is deflected or pressed down a certain distance depending on the weight of the car. Its height under the car is less than its height as manufactured. And when so deflected by the weight of the car the fibres of its metal are stretched. It is evident that a spring whose fibres are only moderately stretched will last longer than a spring whose fibres are pulled to an excessive degree. This pull on the fibres of a metal is known as the stress existing in them. We are now ready to comprehend the significance of a most important fact: *the life of a spring is measured by the stress existing in its fibres when carrying the loaded car.*

Fibre Stress Explained

There need be no cause for regarding stress as a deep and involved technical term. Consider it in every-day language as a measure of the pull in the metal which tells us how hard it is working. In order to compare one stress with another their magnitude is given by stating the number of pounds of such pull which acts on one square inch of metal. Thus, if we state that a spring is stressed to 50,000 pounds, we mean that each square inch of its most stretched fibres will be pulled by a force of 50,000 pounds of weight.

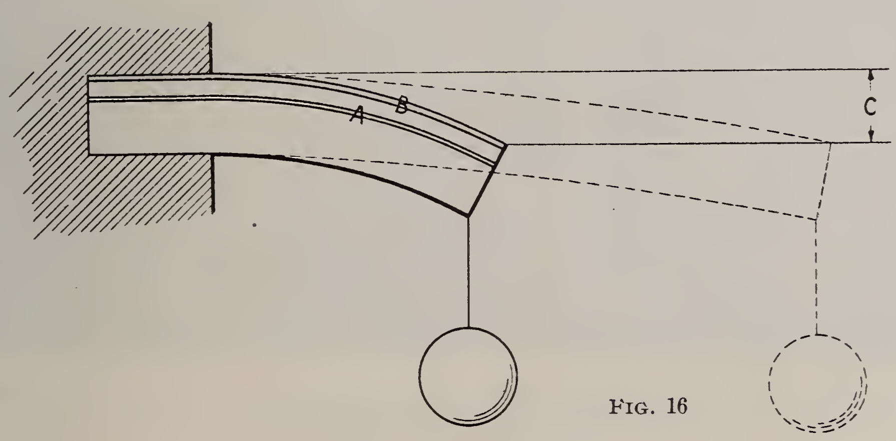
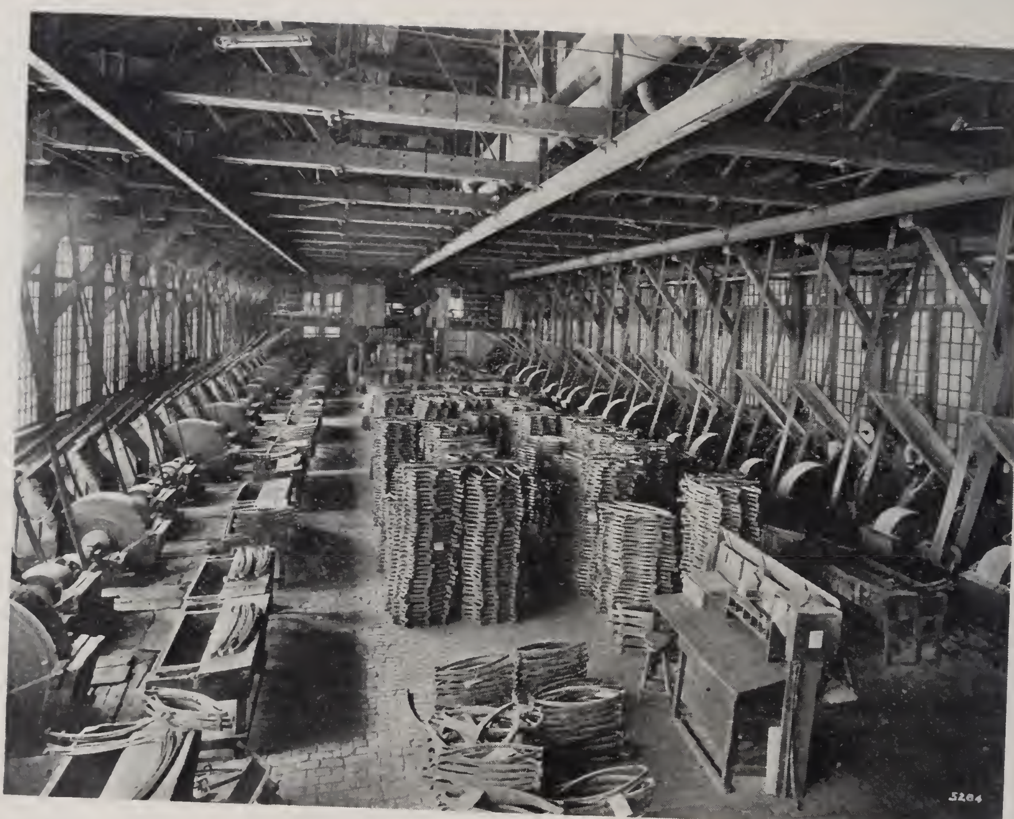


FIG. 16

Measure of Fibre Stress

How can we measure these stresses? What relation exists between them and the dimensions of a spring? Figure 16 shows a bar of steel held in a vise and deflected by a weight at its outer end. The fibres above the center of the bar will be stretched, and the fibres below the center will be compressed. This fact can be made more evident by examining a long pencil eraser bent about in the fingers. The eraser is subjected to exactly the same action as the



GRINDING DEPARTMENT
NUMBER ONE MILL

steel bar; it is merely a body possessing stretch to such a degree as to make itself visible to the naked eye.

Stress is Measured in the Outer Fibres

A represents a fibre near the center of the bar; *B* is a fibre at its surface, an extreme or outer fibre. A little thought will show that for any given amount of bending the fibre *B* is stressed to a far greater extent than the fibre *A*; whence it follows that, in any bar, the outer fibres are the only ones we need examine for stress. They are acted upon most severely, the fibres near the center always being acted upon in a smaller degree. Consequently it is always understood when a stress is mentioned that it is the stress in the outer fibres.

Stress Varies as Thickness of the Leaf

It will also be seen that if our bar had been thicker, its outer or most remote fibres would have been further from its center and for the same degree of bending would therefore have been stressed higher. The relation between thickness and stress is a simple one, namely, that if the bar had been twice as thick, the deflection remaining the same, the stress would have been twice as great. In other words: all other things being the same, the stress in a bar will vary directly as its thickness.

Stress Varies as the Deflection

If we examine Figure 16 again a second fact becomes evident. If we had bent down or deflected the outer end of our bar a greater distance than *C*, all its fibres would have been stressed to a greater extent than before. The relation between deflection and stress is also a very simple one, namely, that if the deflection had been doubled the stress would also have been doubled. In other words: all other things being the same, the stress in a bar will vary directly as its deflection.

Stress Varies Inversely as the Square of the Length

The stress in a bar is also effected by another dimension, its length. If we had increased the length of the bar as shown by the dotted lines and still deflected it only the same amount, the stress would have been much smaller than with the shorter bar, because the angle of bending at the fixed end would have been far less. The relation between length and stress is not quite so simple, but can be given by stating that if the length only of the bar had been doubled its stress would have been only one-fourth as large. In brief: all other things being the same, the stress in a bar will vary inversely as the square of its length.

Thickness, deflection and length are the only factors which influence the stress of a spring. The width of the spring and the quality of the metal have nothing to do with stress; they cannot change it in any way.

Stress is Measured Primarily by Shape Only

Stress is purely a geometrical condition which is influenced and changed only by the linear dimensions of the spring. To sum up: Stress is dependent:

1. On the thickness of the bar.
2. On the amount we deflect its outer end.
3. On its length.

Requirements Demanded by Long Life

We have already shown that the life of a spring is governed by the stress imposed on its fibres when carrying the loaded car; this fact, together with what we have just learned regarding stress, will enable us to appreciate that:

Proper Thickness of Leaf

1. To maintain "life" we must use thin leaves for long life and thick leaves are not compatible; they cannot exist at the same time.

Proper Deflection

2. To maintain life we must maintain small deflections. Long life and large deflections are not to be looked for at the same time. The amount of deflection necessary in a spring is fixed by its riding qualities, and it is therefore not our purpose to say here that a spring must be made hard riding to keep down its stress. Deflection should be the last condition to be changed in a spring if it is found that its stress is high. All other dimensions should be so chosen that with a given necessary deflection the stresses are kept within the proper limits.

Proper Length

3. To maintain life we must use long springs. Short springs will not survive as well as springs of greater length.

The true art of the spring designer steps in just at this point. He must be able to so choose the length of the spring and the thickness of its leaves that for the given necessary deflection the stresses will be such as will permit a reasonable length of life.

Proper Material

4. To maintain longevity we must see that proper material is employed. This would seem to be axiomatic, and in need of no further explanation. There is, however, so much to be said as to the manner in which one steel differs from another that we are strongly tempted to go a little further.

Injurious Deflection of Springs

Elastic Limit

Different Materials Have Different Elastic Limits

It is a matter of everyday experience that if we double the load upon a spring its deflection will be doubled. In a simple spring the deflection varies directly as the load. That relation will, however, not hold true indefinitely, for when a load is increased beyond a certain point the steel is injured. To make this clear examine Figure 1b again and imagine it to be a spring of one leaf. Suppose we increase the load on the bar by increments of 50 pounds, releasing it to its free height after each increase of load. It will be found that each additional 50 pounds produces practically the same increase in deflection and that each time we release the bar we find it to have resumed its original shape. But as we keep on adding weight continually, we will notice that our differences in deflection are no longer the same and uniform, but that they have suddenly increased, each being larger than that preceding. We will also notice that if we now release the load the bar no longer has its former shape; it has been permanently bent. This point in the experiment, at which the bar is permanently bent and at which the deflections begin to increase in greater proportion than the load is called the *elastic limit* of the material. That limit can best be measured by stating the stress which exists at the time. Each kind and quality of metal has its own elastic limit. Wrought iron can be stressed to about 25,000 pounds per square inch without injury, structural steel to from 30,000 to 40,000 pounds, carbon-spring steel after teeatment to 110,000 pounds.

If we now examine an alloy steel in the same way we note a marked and truly wonderful increase in the elastic limit. This

Alloy Steels Have Higher Elastic Limits and Ability to Resist Fatigue

increase in the elastic limit, together with the accompanying ability to resist fatigue, are the essential characteristics of alloy steels. We can point out a certain Silico Manganese steel, made in the electric furnace, which has an elastic limit of 220,000 pounds per square inch. The vast advantage of such a steel can easily be comprehended. A bar of it held in a vise could be bent just twice as far without injury as a carbon steel bar of the same dimensions. This does not mean

Electric Furnace Silico—Manganese Steel

that a spring of this alloy will merely last twice as long as a similar carbon spring. The ratio between the two is very much greater than this. For in addition to having a high elastic limit these steels also possess remarkable anti-fatigue properties. Instead of only doubling the life of the spring by employing alloy steel we increase its life many fold.

5. To maintain life we must see that our material is properly tempered, that its heat treatment is correct. We have said

Heat Treatment of Spring Steel

little on this point so far and fear that its importance may therefore not be appreciated. Each kind and grade of steel requires its own particular heat treatment to enable it to endure, and anything short of that treatment should not be tolerated. The most expensive alloy, if improperly treated, is inferior to carbon steel which has been so treated as to bring out all its good points. In this connection uniformity must be maintained. The temper must be correct in all the leaves and the same in one spring as in another.

What relation exists between length of life and weight of the spring itself? We have already mentioned that the deflection

Relation Between Endurance of a Spring and Its Weight

of a spring from its free height to its height under the loaded car determines its riding qualities. Deflection having been fixed, we can support the given load by using a small number of thick leaves or a larger number of thin leaves, *the riding qualities being practically the same.* The spring with thick leaves will be comparatively light, the spring with the larger number of thin leaves will be the heavier of the two. But we have made it evident that thin leaves result in low stress and therefore longer life. This fact leads us to admit that a heavy spring with many thin leaves will last longer than a light spring having only a few thick leaves. The increased weight goes directly into increased life. For the same riding qualities, by reducing the thickness of the leaves, we can extend the life of a spring indefinitely. We can get as much life as we think poper for the service in question. The happy mean in weight must be chosen, and here again the skill and experience of the designer show itself.

Increased Weight Goes Into Life

In laying out a spring the first dimensions to be determined are its length and width. They are closely connected one with the other. If not properly chosen an efficient suspension is not possible. Thus, if a spring is too long it will be heavier than needed for the required service. If too short it will be either stressed too high and its length of life thereby shortened materially, or it will be hard riding, due to having been stiffened to cut down its stress. The factors influencing length and its corresponding proper width are many, too many to be fully discussed here. Instead of going into such a discussion we insert a table giving lengths and widths for pleasure car springs which will produce proper riding, as well as proper lasting qualities, provided, of course, that there is ample clearance.

Proper Spring Lengths for Pleasure Cars

The loads are those which the spring will carry when the car is loaded with its rated number of passengers. The lengths are those which the springs will have when so loaded.

Front Springs

Load on One Spring	Length	Width
350 to 400 Pounds	33″ to 34″	1½″
400 " 450 "	35″ " 36″	1¾″
450 " 500 "	35″ " 36″	1¾″
500 " 550 "	36″ " 37½″	1¾″
600 " 800 "	37½″ " 40″	2″
800 " 1,100 "	40″ " 42″	2¼″

Rear Semi-Elliptic Springs

Load on One Spring	Length	Width
450 to 550 Pounds	46″ to 48″	1¾″
550 " 650 "	49″ " 50″	2″
700 " 850 "	51″ " 52″	2″
900 " 1,000 "	52″ " 55″	2¼″
1,000 " 1,350 "	55″ " 57″	2¼″
1,350 " 1,550 "	57″ " 60″	2¼″ to 2½″

Rear Three-quarter Elliptic Springs

Load to One Spring	Length of Semi-Elliptic Element	Length of Scroll (Link to Centre Bolt)	Width
450 to 500 Pounds.	45″ to 47″	18″ to 19″	1½″
500 " 650 "	47″ " 49″	18″ " 19″	1¾″
650 " 775 "	47½″ " 51½″	19½″ " 22″	2″
775 " 900 "	51½″ " 25″	22½″ " 23″	2″ to 2¼″
900 " 1,000 "	52½″ " 53½″	23″ " 24″	2″ " 2¼″
1,000 " 1,150 "	53½″ " 54″	24″ " 25″	2″ " 2¼″
1,150 " 1,250 "	54″ " 54½″	25″ " 25½″	2″ " 2¼″
1,250 " 1,350 "	54½″ " 55″	25½″ " 26″	2″ " 2¼″
1,350 " 1,450 "	55″ " 56″	26″ " 26½″	2¼″ " 2½″
1,450 " 1,550 "	56″ " 58″	26½″ " 27″	2¼″ " 2½″
1,550 " 1,650 "	58″ " 60″	27″ " 27½″	2¼″ " 2½″

Full Elliptic Springs

Load on One Spring	Length	Width
500 to 550 Pounds	35″	1¾″
600 " 700 "	35″	1¾″
800 "	36″	2″
1,000 "	37″	2¼″
1,100 "	39″	2¼″
1,200 "	41″	2¼″
1,300 "	43″	2¼″
1,400 "	44″	2½″
1,500 "	45″	2½″
1,600 "	46″	2½″

Three-quarter Platform Springs

Load on One Side Spring		Length of Side Spring	Length of Cross Spring	Width
500 to 550	Pounds	45″ to 47″	39½″	1¾″
600 " 700	"	47″ " 49″	39½″	1¾″
900	"	51″ " 53″	39½″ to 40″	2″ to 2¼″
1,000	"	53″ " 55″	39½ " 40″	2¼″
1,100	"	55″ " 57″	39½″ " 40″	2¼″
1,200	"	57″	40″	2¼″
1,300	"	57½″	40″	2¼″
1,400	"	58″	40″	2¼″
1,500	"	58½″	40″	2¼″

PART VI

ANALYSIS OF A SPRING SPECIFICATION

Foreword to Writers of Specifications

We come now to the matter of spring specifications. We have already said that our object in writing these lines is to enable the car builder to make known his wants so clearly as to avoid correspondence, or at least to enable him to reduce that correspondence to a minimum. That aim may, perhaps, be fulfilled in two ways. We can tell him what facts are wanted, or we can tell him what facts are not wanted. We will tell him in due course what information is needed, but, just at this point, we believe it will be best for all concerned to examine a faulty specification and see wherein it fails to supply the information required. In so doing we hope not to reflect upon the ability of the car builder, for we realize perfectly that he is a busy man who cannot be expected to go as deeply into our work as we have gone and that he has many other parts of the car to consider.

A car builder orders as follows:

TEN PAIR FRONT SPRINGS 36″ LONG, 2″ WIDE, 6″ HIGH. NUMBER OF LEAVES, SEVEN. FOR FIVE PASSENGER CAR WEIGHING 4300 POUNDS.

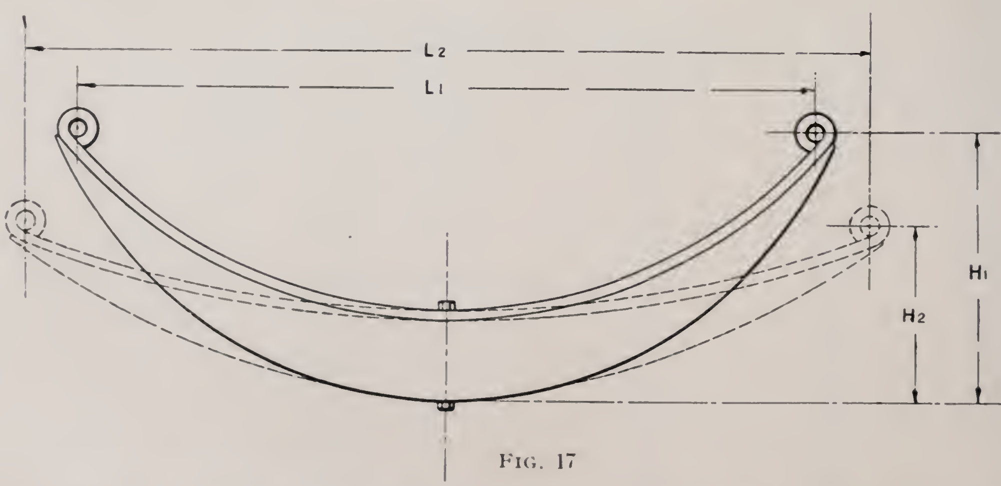


FIG. 17

In connection, first, with length. Figure 17 represents a spring whose curvature has been purposely exaggerated. The

Length of a Spring Is Variable

full lines show its shape as manufactured, "free" or "on the floor," as it is sometimes termed. The dotted lines show its shape after applying a load. Imagine weights of say 50 pounds placed one at each end of the spring, equivalent to a load of 100 pounds acting downward upon the axle. What happens? As the weights are applied the curvature of the spring decreases—it becomes flatter. And as it flattens, the eyes move away from each other; so that the original length of the spring L_1 is increased to L_2. The amount of flattening and increase of length depends on how much load we place upon the spring, and we are forced to admit that: *a spring has no one fixed length. It has various lengths depending on the magnitude of the load it carries.* We have been told to make our spring 36″ long. We accordingly ask: Is this to be its length as manufactured or when carrying the empty car or when the rated passenger and freight load is being carried? Each condition of loading has its corresponding spring length. If the spring shackles hang properly with one load they may not hang properly with another load. The differences in length are small, to be sure, and may not incline a spring shackle unduly one way or the other, but why not have the shackles hang correctly with that condition of loading which exists most often in service.

Height of a Spring Is Variable

Another fact will be noted in connection with Figure 17. If the action of the load be considered for but a moment it will be seen that the eyes are lowered as the load falls upon them and the original height H_1 decreases to H_2. We are then forced to admit this second fact that: *a spring has no one fixed height, but various heights, depending on the magnitude of the load it carries.*

We note that our spring is to be 6″ high. Is it to be of that height when free or when carrying the empty car? Or shall it measure 6″ when the rated load is being carried in the car?

Each Variation of Load Changes the Length and Height of a Spring

Is it not now evident that each load has a length and a height which corresponds to it? All of which may be boiled down into one simple statement, and that is what we now wish to impress most of all upon anyone writing a spring specification: *a spring length and spring height mean little to a spring maker unless he knows in addition at what load each is to be measured.*

FORGING DEPARTMENT
NUMBER TWO MILL

Outside Height

Inside Height, Opening

When the height of the spring is measured from the spring seat to the center line of the eyes (see Figure 1) it is called the "outside" height. If so measured the above spring would have been termed "6″ out." When the height is measured from the top of the master leaf it is called the "inside" height or "opening." If so measured, the spring would have been "6″ open."

Proper Way of Specifying Cambers

The inside height or opening of a spring should be specified only when it is underslung, that is, secured below the axle. When placed over the axle the outside height should in all cases be given. We still find designers who insist on giving the opening when a spring is above the axle. They do not seem to realize that in their case the distance from spring seat to the center line of the eyes is the essential dimension, and that this dimension will vary with the thickness of the spring at its center when the opening is specified.

Number of Leaves and Their Thickness to Be Left to the Spring Constructor

"The spring is to have seven leaves." How has our customer arrived at such a decision? If we give him seven comparatively thick leaves his spring may be too stiff; if, on the other hand, we give him seven thin leaves, his spring may be too soft, or as he may term it, "sloppy." We may or we may not be able to so choose the thickness of the seven leaves that they will best fulfill all requirements. We may as well immediately state that *the number of leaves and their individual thicknesses are questions which should be left entirely to the spring builder for solution.*

Matters affecting the Number of Leaves and Their Thicknesses

They are influenced by so many conditions and so many factors must be considered in determining them that it is entirely beyond the knowledge of the usual spring buyer to specify them properly. We must, for instance, consider the type of car and kind of service, the life of the spring, the kind of material and its heat treatment, the weight to be carried, the distribution of the material of the spring, its appearance, its cost and consequently its weight.

The final term of the specification reading, "The car will weigh about 4,300 pounds," brings us to an item in the specification

Give total Load each Spring Must Carry

whose importance is seldom appreciated. We ask that the following be noted most carefully. *A spring engineer, in order to intelligently design a spring, must know the total load in pounds which that spring is to carry.* Let us not question here just why this information is necessary. Accept for the present our statement that without definite knowledge of load a spring cannot be designed to ride well or have a reasonable length of life.

Springs Obtained by Rule-of-Thumb Method Sure of Eventual Failures

It may be argued by certain of our readers that they have obtained springs without going into details as to loads. That is probably true, and in that case the springs were specified in one of two ways. First, by allowing the spring constructor to assume from his pervious experience what the loads would be. His success in that case was more or less problematical. Or, secondly, the reader may have gotten his spring by changing an old spring design, lengthening and shortening, widening and narrowing, raising and lowering, adding a leaf here and removing one there until the final result rode well and had a reasonable life, the length of which he left for the future to decide. Such can hardly be dignified by the name designing. In the end it is sure to lead to trouble. We will say nothing as to the cost of such a method.

Loads Must Be Definitely Known

We are told that the car weighs about 4,300 pounds. Is this the weight with or without passengers? Was this car loaded or not loaded? We may be told that there were five passengers in the car when the weight was recorded. We then ask how much of this total weight came on the front end. We may be told that "about" four-tenths of the total load is on the front end. Or we may be informed that the front wheels only were placed on a platform scale and showed a weight of 1,800 pounds. That is definite information, but still far from complete. Upon reflecting a moment it will be seen that not all of the weight of the front end rests on the springs. Wheels, axles, springs and attached parts are dead weights, in which we are not interested. They are not carried on the springs. The dead weight if not specified must be estimated by the spring maker as best he can. We accordingly ask, "What part of the 1,800 pounds rests on the springs?" We may be told that 1,550 pounds is so placed. Are we to assume that the right and left sides of the car weigh the same. In short, and let this be observed thoroughly: The spring maker must know the weight in pounds on each spring, front and rear, right and left, and he asks that these weights be recorded when the rated number of passengers or amount of freight is in the car. It will usually be sufficient to state the load for the two front springs collectively and for the two rear springs collectively. In so doing it should be determined from an inspection of the design of the car that the right side will weigh approximately the same as the left side.

Right and Left Hand Loads Desirable

PART VII

SUGGESTIONS OF METHODS FOR OBTAINING WEIGHT OF THE CAR

Loads from an Experimental Model

Having dwelt at such a length on the importance of specifying the exact weights which a spring is to carry, it is to be expected that we give some directions as to how this information can be secured. In doing so we will have to consider whether the car is still on paper or whether an experimental model has already been constructed. Matters will be considerably simplified if such a model is at hand, and we will accordingly discuss this case first.

Freight or Passenger Load Must Be in Place When Getting Loads and Dimensions

Let us assume, then, that the experimental model is ready and has a set of springs under it somewhat similar to those which will finally be used. How is the weight resting on each spring to be found? Obviously the most rational way to get the information will be to weigh the car. Before this is done care should be taken that it is in full trim and running order. All accessories and equipment should be in place, radiator and tanks filled. And last but by no means least, the rated number of passengers or freight should be in the car when these measurements are taken.

Front End

Drive the car upon a platform scale and record its total weight. Back the car off so that only the front wheels remain on the scales. This will give the total weight of the front end. When only part of the car is on the scales *make sure that the car stands level.* If tilted to any great degree the weights recorded will not be correct.

Rear End

Now run the car across so that only the rear wheels remain on the scales. Record the total weight of the rear end. See that the front and rear weights just recorded check up with the total weight of the car.

Weight of Right and Left Sides

Run the right front wheel only on the scales. Record its weight. The difference between this and the total front weight will give the weight of the left front wheel. Or, better still, weigh the left front wheel also and see that the weights of the two wheels check with the total front weight.

Do the same for the rear end of the car, getting the weight of the right and left sides. Finally, as a matter of record, weigh the entire car empty; also weigh the passengers or freight as a unit.

So much for the car as a whole. We must still find the weight of such parts as do not rest on the springs.

Weight of Parts Not Supported by Springs

Remove the front axles from the car with wheels and springs still attached. Weigh all these as a unit. If parts are kept in stock it will be more convenient to weigh them individually and record their total weight.

To get the weight of the unsprung parts as just described is without doubt a somewhat troublesome proceeding. The labor expended will, however, be repaid many fold in knowing that all this has been done toward getting the best of spring efficiency. We give below the actual figures as recorded in getting the spring loads from a recent car.

Total Weights

A Typical Case in Detail

Total weight with five passengers	4,300	pounds
Total weight front end	1,795	"
Weight under left front wheel	875	"
Weight under right front wheel (by difference)	920	"
Total weight rear end	2,475	"
Weight under left rear wheel	1,185	"
Weight under right rear wheel (by difference)	1,290	"
Weight car empty	3,465	"
Weight of the five passengers	850	"

STEEL STOCK
NUMBER ONE MILL

This contains stock for this mill only and is but a fraction of the entire stock carried

Unsprung Weights

Weight of the front axle	71	"
Weight of front wheels, tires, springs, etc	176	"
Total dead weight front end = 71 + 176	247	"
Weight of rear axle	321	"
Weight of rear wheels, tires, springs, etc	206	"
Total dead weight, rear end = 321 + 206	527	"

Weight on Springs

Weight on left front spring 875 less $\frac{1}{2}$ of 247 = 751 pounds.

Weight on right front spring 920 less $\frac{1}{2}$ of 247 = 796 pounds.

Weight on left rear spring 1,185 less $\frac{1}{2}$ of 527 = 921 pounds.

Weight on right rear spring 1,290 less $\frac{1}{2}$ of 527 = 1,026 pounds.

Check Heights and Lengths with the Assembly Drawing of the Car

Before concluding the tests check up the lengths and heights of the experimental springs. Run the car upon a smooth and level floor, the passengers still on board, and measure the height of the frame above the floor, both front and rear. Note difference in level if any. Stretch a fine string across the front spring from eye to eye. Measure the height of this string above the spring seat. Add or subtract from this height whatever is required to bring the car to the desired front height and record this corrected measurement as the height to be specified. It should agree with the corresponding height on the assembly print of the car. Do the same for the rear of the car.

Note Shackle Position

Measure the center length of the front spring. Note position of its shackles. From the position of these and the length just measured, record the length of the spring to be specified. It should agree with the length already found on the assembly print.

Analysis of Weights of Greatest Value to All

This is the simplest, most direct and most accurate method of getting spring data. It should invariably be worked out before ordering springs in quantities. Send the results so recorded to the spring manufacturer, together with a comment on the riding qualities, and he can ask for nothing more. We find many builders on checking up sample springs, telling us merely to raise or lower the springs by given amounts. Such information is acceptable and often adequate, but, if at all possible, we earnestly urge that an analysis be made such as we have described above.

Other but Indirect Methods of Obtaining Weights There are other methods of getting the weight on the springs. They are not as direct as the above, and should be used only when approximate figures are sufficient.

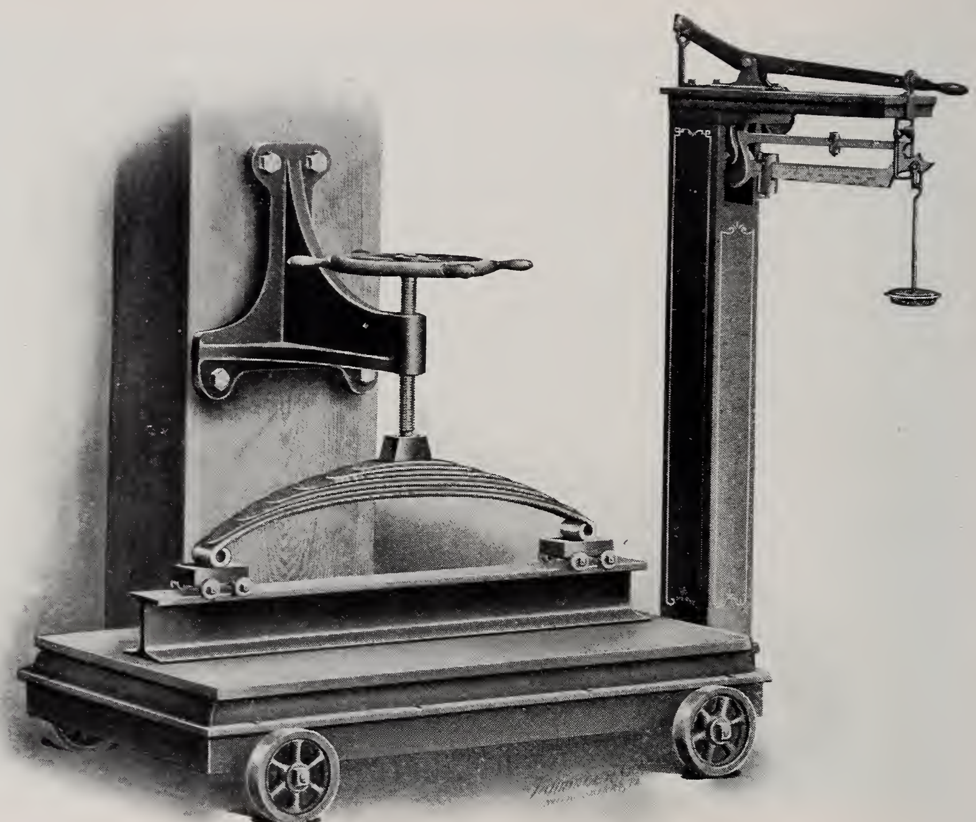


Fig. 18.

The first of these methods is as follows: Stretch a string from eye to eye of the spring and note carefully the height of this string above the spring seat. Remove the spring from the car and place it upon a platform scale equipped with a screw jack similar to that shown in Figure 18. Record the weight of spring and other parts on the scale. Now apply pressure to the spring, deflecting it until it again stands at the same height as it did when under the car. Record this second weight. The difference between the

First Approximate Method

first and second weights will be the weight carried by that particular spring. A tensile testing machine may be employed for this purpose. But because of the large loads for which it is constructed will hardly be as sensitive as the smaller platform scale or as accurate.

It should be noted that this method does not require that a spring be used which was designed for the car under investigation. Any spring may be used which will fit the car. The spring in this case becomes a weighing mechanism and serves the same purpose as the helical springs in the familiar spring balances used by shopkeepers.

The only objection that can be made to getting the weights in this way is the part played by friction, which is apt to vary the results.

The Inaccuracy Caused by Friction of Leaves

To show that friction effects the deflection of a spring proceed as follows: Having balanced the scale with the spring upon it, compress it gradually, turning the screw jack always in the downward direction, until the desired height is reached. Record the weight. Now compress the spring, say 1″ beyond the desired height and gradually unscrew the jack, turning it always in the upward direction until the desired height is again reached. Record the weight.

Neutralizing Friction Partly by Rapping

It will be noticed that the two weights are quite different, the "downward" weight being larger than the "upward" weight. This difference is caused by friction between the leaves, which retards the motion of the spring. The effect of friction can be partly neutralized by rapping the spring several times with a hammer, both when under the car and when under test.

Should no platform scale of sufficient size to weigh the entire car be handy, approximate spring weights can be had as follows:

A Second Approximate Method

Remove the front axle, the springs remaining on the car. Roll a small portable scale under the middle of the car with a small screw jack upon it. On top of the jack place a wooden beam long enough to span the distance between the two spring seats. Raise the jack until the car is at the desired height. Record the weight and subtract from it the weight of jack, beam and springs.

All these methods suppose that a car has already been constructed or at least that a chassis more or less complete can be weighed and measured. What is to be done when the car is still on paper? In this case approximations to the weights on the springs can be had by the following method. It will be necessary to know the weight of each part of the car and the horizontal location of the center of gravity of each part. Such information the manufacturers of the various parts should be able to furnish.

Getting Loads Before a Car Has Been Constructed

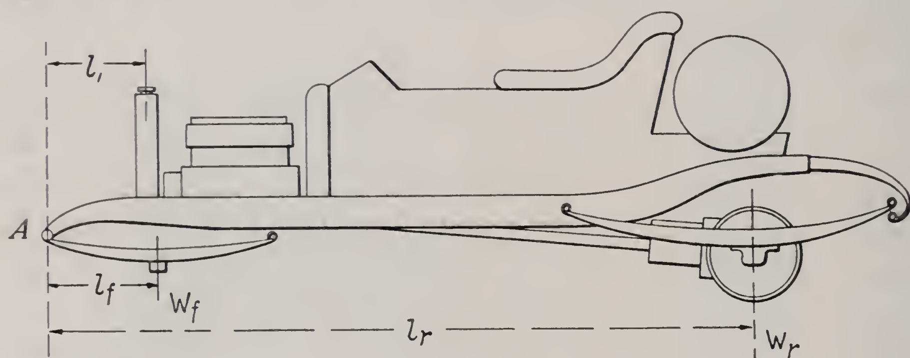


FIG. 19

The method is based on the principle of moments. Consider *A*, Figure 19, as the center of rotation. Each part of the car may be considered as tending to rotate the car downward. The tendency to rotate will be the moment of the part about *A* as a center. That moment will be the weight of the part multiplied by its horizontal distance from *A*. Thus, if the radiator weighs 100 pounds filled and the distance l_1 is 12″, the moment of the radiator will be 12 x 100 or 1,200 inch pounds. In a similar way the moments of all the other parts about *A* may be found.

Method of Balanced Moments

The sum of all these will be the total moment tending to rotate the car downward about *A*. Represent it by Σ M, the sign Σ standing for "sum." This total downward moment will be resisted by the moments produced by the front and rear spring loads acting upward. Let the load on one front spring be W_f and the load on one rear spring be W_r. Also call the distance from *A* to the front axle l_f and the distance from *A* to the rear axle l_r The moment of each front spring load will be $W_f\ l_f$ and the

Summation of Moments

moment of each rear spring load will be $W_r l_r$. We can now write the equation :

$$2\ W_f\, l_f + 2\ W_r\, l_r = \Sigma M$$

in which W_f and W_r are the unknown quantities. All the loads should be in pounds and all the distances in inches.

We also know that the spring loads as a total must equal the combined weight of all the suspended parts. Call the total weight of these parts T. We can then write:

$$2\ W_f + 2\ W_r = T.$$

A Method Within the Scope of Modern Engineering Departments

We now have two simple simultaneous equations which can readily be solved for W_f and W_r. We admit that all this is cumbersome, tedious and requires more or less engineering knowledge in its solution. But we fail to see why it should be beyond the capacity of any modern engineering department.

PART VIII

MODEL SPECIFICATIONS FOR LEAF SPRINGS

We come right down to the point now, where a specification is to be written—where we prepare a statement which is to show the spring builder what is required.

Suggestions for the Preparation of Specifications

Before going ahead we are tempted to make a few suggestions as to the preparation of drawings and blue prints, and we trust that in so doing we will not be regarded as over critical. We will make springs no matter in what fashion you send in the information, for any and all drawings and prints and sketches are welcome. We will digest them all, for we have spent many years in tasks just such as these. We offer this advice in the hope that it may result in eliminating those small perplexities which take up our time and prevent us from getting down immeditaely to a proper interpretation of your requirements.

We Prefer a Print, Not a Pencil Sketch.

We ask that the car builder submit us a print showing what he requires and in which he may embody such facts as we will shortly ask for. Note that we ask for a bona-fide blue print. Do not send a pencil drawing. If you do, you will have no fac-simile record of your own to refer to. Do not send the tracing itself. Keep it so that you may make prints for your own use. And we earnestly ask that you do not make prints from a pencil drawing upon transparent paper. Such prints are seldom legible. They are acceptable, to be sure, but is not the work of inking in such a drawing small compared with the improvement which results. We recall cases in which much puzzling and consultation was necessary before arrow heads could be distinguished, or dimension lines followed up, or the figures themselves deciphered.

Legibility of Figures and Dimension Arrows

Firm's Name on Prints

Place the name of your firm on the print. The spring maker has hundreds of prints. They pass through many hands. If your print should become detached from your letter or order he may not be able to identify it without considerable searching and consequent delay.

Number Your Prints

Number your prints. If you do, you can much more readily refer to them in correspondence. Place some symbol upon the print so that the designer may know that he has your latest edition of it. He has all your prints gathered together. If not properly marked he may accidentally pick up an obsolete issue of the print. A simple method of noting revision is to place after the print number a new letter each time a change is made upon it. Thus, if the original issue is 1,296, call the first revision 1,296A, the second revision 1,296B, etc., etc., changing the issue letter every time the print is corrected in any way. Many place a list of the revisions upon the print. This is admirable, but does not show at a glance that the latest issue is at hand.

Issue Letters

Specification for a Semi-Elliptic Spring

In print 100, we submit model specification for a semi-elliptic spring. Note that the spring is drawn only in outline except that the top leaf is shown. When checking up a drawing *look over the following list* to see that no items have been omitted. *All dimensions and loads should be stated as they are to be when the car is carrying its full rated load.*

Details to Be Included in Specifications:

Width

1. Width of steel in inches.

Lengths, Partial and Total

2. Total length center to center of eye, always measured horizontally. The partial lengths, from eye to center bolt, also measured horizontally. State which end is the front end.

Height or Camber

3. Height from the spring seat to center line of eyes. This dimension should be given *as it is to be when full rated load is in the car.* If for any reason the height at the rated load cannot be given, give the height for the empty car. In any case give length and height *which correspond to the given load.* This is very important.

4. If one end of the spring is lower than the other, show the difference in height. The difference in height to be measured from the lower eye to a line drawn horizontally through the upper eye, that is: parallel to the spring seat. Such a difference in height is called a *drop*. When the eyes are at different heights do not measure the center distances along inclined lines; measure them horizontally just as though one eye were at the same height as the other; further, when the eyes are at different heights be careful to keep the spring seat horizontal or "level." The spring manufacturer will make it so unless otherwise directed.

Height at Each End

Level Seats

5. Show inside diameter of each eye. If they are to be bushed show a bushing on the drawing and state of what material it is to be made. The outside diameter of the bushing, however, need not be given. If for good reason there is limited room at the ends of the spring show the outside diameter of the eye itself. This should usually be left to the spring designer for decision, as it is always the best policy to have him make it as large and strong as he can.

Inside Diameter of Each Eye

6. Give the load which the spring is to carry when the dimensions are as shown. This should preferably be given *with the rated load in the car.* In any case state the condition of loading which the given load represents; that is, state whether the given load is based on the rated load or includes a stated percentage of overload.

Load on Spring

Oil Holes

7. Show location of oil holes if they are desired; give their details.

Spring Seat

8. Give length of the spring seat.

9. Give the amount of clearance. By clearance we mean the distance which the suspended part of the car may be lowered beyond its loaded condition until any two adjacent parts strike each other. When measuring for clearance be sure to examine all parts of the car. Mud guards, spring brackets and other side parts are just as liable to decrease clearance as parts underneath the car.

Clearance

Front or Rear, Class of Service

10. State whether the spring is a front spring or a rear spring. Give type of car and some indication of the class of service in which it is to be used.

"Plain End" Spring

In print 101 is shown a semi-elliptic spring having a "plain end" at each end. The only additional dimensions necessary are the center length and overall length. They are required in order that the ends may be properly shaped and the spring tested under conditions the same as those which exist in service.

Platform Cross

In print 102 is shown the cross spring of a platform rear suspension. If possible, keep the eyes turned as shown in this drawing, because such a construction is the strongest. We have already referred to this in Part III.

Order Springs in Sets

It is not advisable to specify and buy the cross spring separately from the side springs. Specify the whole platform suspension at the same time. The actions of the cross and side springs are so intimately connected that it is not desirable to design one without knowing the characteristics of the other. It is only by designing and making them at the same time that proper riding qualities and low stresses may result. If they are designed independently it is very easy to throw upon one or the other more than its proper share of the total deflection. The stresses in either the side or cross may therefore become high and reduce its life materially.

When only Cross of a Platform Is Ordered Prints of the Side Springs Should Be Sent

When the entire platform suspension is specified at the same time it will not be necessary to give the load carried by the cross spring, its load can always be determined from the load on the side springs. When the cross is specified by itself and the spring maker knows nothing about the side springs with which it is to operate the load on the cross spring should always be specified.

Three-Quarter Scroll Elliptic

In print 103 we show model specification of a three-quarter scroll elliptic rear spring. Many of the remarks made in connection with semi-elliptic springs will apply equally well to three-quarter springs. The height of the front eye above the lower spring seat is an important dimension. The height of the whole spring should be measured from the lower spring seat to the upper spring seat. In the spring shown, the spring seat of the quarter spring is underneath it. The height there given is measured from the inside edge of the quarter spring to the outside edge of the semi-elliptic spring, and is therefore called the "in to out" height of the spring. In rare cases, when the upper spring is fastened below its bracket, and the spring seat of that spring is above it, the height of the whole spring is measured from the outside edge of the lower spring to the outside edge of the upper spring. This height is called the "out to out" height. In all cases the aim should be to *measure the height from the face of one spring seat to the face of the other.* The horizontal distance between the two center bolts should in all cases be given, also the horizontal distance from the upper bolt to the front end of that spring and from this bolt to the links.

"In to Out" Dimension

"Out to Out" Dimension

The curved part at the end of the quarter element is called the "scroll." The details of this may be left to the spring designer, but a statement as to what style or size of scroll is preferred is not undesirable. State, for instance, whether it is to be small or large or like a certain previous order. In any case do not place an arbitrary scroll on the drawing; shape it as nearly as possible like that which you wish furnished.

Scroll Style and Details

In Part VII many points in connection with three-quarter springs are brought up. Look them over carefully before checking up your drawing.

Print 104 shows specification of full elliptic spring with a head at each end. In such springs the inside height or "opening" under load usually determines the clearance. The opening should, therefore, be determined approximately and carefully examined before finally sending out designs for this class of springs. It is still advisable, however, to measure the height of the spring from spring seat to spring seat.

Full Elliptic

Examine Opening Carefully

Double Scroll Full Elliptic

Print 105 shows specification of double scroll full elliptic spring. Remarks previously made as to style of scroll and inside height, apply also to this class of spring.

PART IX

CONSIDERATION OF IMPORTANT DETAILS

Spring Fastenings

The fastenings of a spring are in many respects as important an item of design as any part of the spring itself. If the fastenings are poorly designed, or, if when properly designed, they are allowed to become loose, spring breakage will result. Just why this breakage occurs is too lengthy a matter to discuss here. The fact remains that if, after taking all precautions to get proper stresses, material, heat treatment and workmanship, the spring seat is faulty or the box clips are permitted to get loose, breakage will inevitably occur. By box clips we mean the clips at the center of the spring which fasten it to the axle. It is urged, therefore, that great pains be taken to get a proper design for the spring seat and box clips and to have the latter of ample size. The aim should be to have that portion of the spring between the clips so well secured as to keep it perfectly rigid and inert; so that it may more properly be considered part of the axle than part of the spring itself. When but two clips are used see that they are sufficiently strong. The following is a simple statement of the *minimum diameter* allowable for clips in *pleasure* cars:

Loose Clips Cause Breakage of the Spring

Box Clip Diameters

Spring $1\frac{3}{4}''$ wide and under	$\frac{1}{2}''$ to 9/16″	diameter
" 2″ wide	9/16″ to $\frac{5}{8}''$	"
" $2\frac{1}{4}''$ and $2\frac{1}{2}''$ wide	$\frac{5}{8}''$ to $\frac{3}{4}''$	"

Bear in mind that these are the *minimum* diameters. Heavy springs, especially in trucks, require heavier clips than those listed, and should be carefully figured for stress in the clips. No general rule can be given at this time, except that they will vary from 9/16″ to $1\frac{1}{8}''$, depending on many things.

Some statement will be here expected as to shape of the spring seat. It is evident that the shape of the spring itself

Shape of Spring Seat

changes at the center under different conditions of loading and deflection. It is, consequently, not possible to so shape the seat as to fit the spring under all conditions, and it would hardly seem necessary to suggest that the next best thing would be to make the seat conform to that shape of the spring which exists most frequently in service.

"Packing" at the Spring Seat

To make the spring fit well to its seat and to allow for small irregularities of the surface in contact a thin packing should be used between seat and spring. This packing should be firm and so thin that it will not compress or flatten out in service and so loosen up the clips. Two thicknesses of 6 or 8 oz. duck, saturated with white lead, has been found to act well.

Strapping Spring With a Third Clip

An admirable way to prevent breakage of springs at the center is to use a third clip to strap the spring down directly over the center bolt. Such a clip would usually consist of a stud at each side of the spring, spanned by a cleat across the center bolt. Where it is not convenient to use this arrangement, a fair substitute is to use what may be called a pressure-block under the clips above

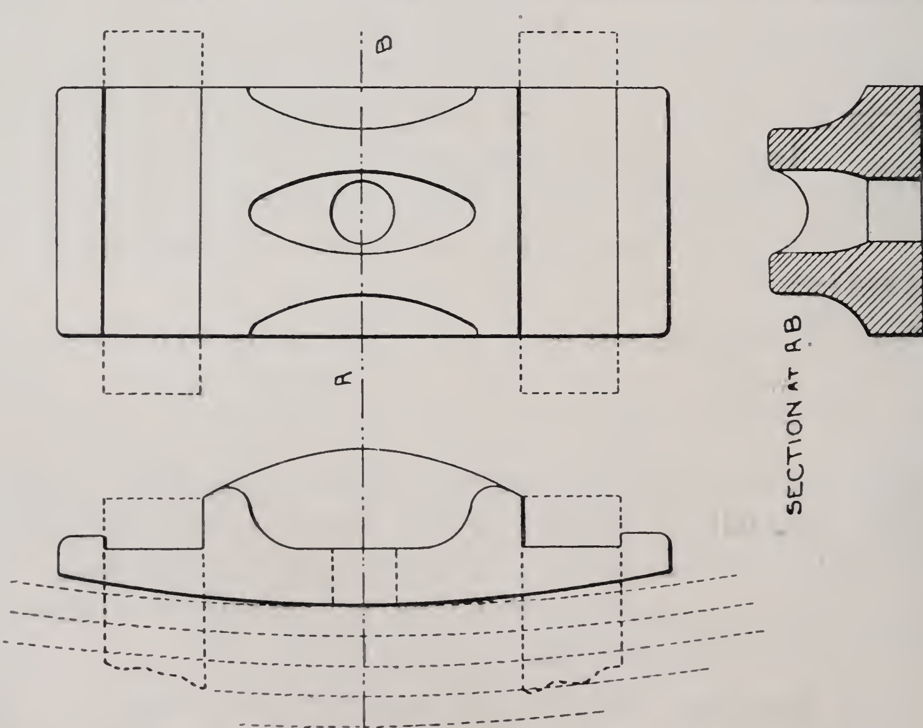


Fig. 20

the spring. This block should be of steel, with its lower surface shaped to a slightly greater degree of curvature than that of the upper surface of the spring. Its ends will then not touch the spring before tightening the clips. When the clips are tightened they will tend to straighten out the block, making it conform to the shape of the spring and producing pressure over the center bolt hole, see Figure 20.

Pressure Block to Hold Spring at Center Bolt

The whole question of spring fastening has been very well summed up by one of our engineers, when he states: "When spring fastenings are so well designed that they would hold a spring which has been sawed in two through the center bolt hole, no breakage will occur between the clips."

We repeat that the best of fastenings is useless if the clips are allowed to loosen, and strongly urge that car builders bring this point to the attention of car owners. Proper mention should be made of it in the instruction books and its importance set forth in such manner as to keep it constantly before the man who uses the car. He should go over his clips at least every thousand miles to see that they are tight.

Car Owner Must Keep Box Clips Tight

Spring seats should be carefully inspected to see that they are level, transversely. If uniformity cannot be secured in this respect from seats as forged, they should be machined. A spring seat which is not level transversely will produce a torsion or twisting in the spring. Such torsion creates an additional stress which is entirely uncalled for and hastens breakage.

Level Spring Seats

In some cars the front end of the rear springs is used to transmit the driving force from the axle. When so used the spring serves two distinct purposes; it is used as a variety of beam to support the weight of the car above it and as a column through which to push the car. As a straight column is stronger than a curved column, it follows that the part of a spring which transmits the driving force should be kept comparatively straight and flat. Notice another fact. The master leaf of a spring is the only leaf connecting frame to axle; if that leaf is not well clamped to the other leaves by rebound clips

When Spring Takes the Driving Effort, Keep it Flat

it will transmit the entire driving effort in itself, tend to open up the spring by buckling and finally break. We have already mentioned this in Part III, in connection with clips. *Always advise the spring manufacturer of the fact when driving effort is to be taken through a spring.*

The scroll portion of a three-quarter spring is in some cases made to fit into a place prepared for it in the end of the frame.

Do Not Prescribe Thickness of the Scroll Element

In order to make the scroll element fit into this part of the frame some builders specify that it shall be made of a certain prescribed thickness at the bolt. To have the scroll fit the frame nicely is most desirable. But we respectfully ask that the spring maker be consulted before designing this part of the frame. Make that part of the frame fit the spring rather than make the spring fit the frame. Allow the spring designer full play as to thickness of scroll so that he may choose such a number and thickness of leaves as will produce the best riding and longest life. If the thickness is specified he may either have to build up the spring with unnecessary material or he may be so restricted as to use too little material and thereby obtain high stresses in what he does use. In short, "make the shoe fit the foot" rather than force the foot to fit the shoe.

In our model specification for a three-quarter spring it will be noted that on the scroll element we ask for a short dimension

"Flat Top"

running back from the center bolt. This is the amount of "flat top," or distance along which the scroll is to be kept straight, so as to fit into the frame or attach properly to the spring bracket. When testing a spring the spring maker aims to attach the scroll to his testing machine in the same manner as it is afterward attached to the car. To do so he must know the amount of "flat top."

Shape of Springs

A few remarks should be here made as to the shape of springs in general, and more especially as to the shape as effected by the height of the spring.

Experience as well as theoretical reasoning shows that a spring rides better and looks better if made so that it is comparatively flat under load. Let us see why this should be so.

How does the shape influence the riding qualities? In Figure 21, let the length of the line *W* represent the weight or load acting at the end of the spring. By a simple parallelogram of forces the load W can be resolved into a force A, acting along the spring, and a force P, acting perpendicular to it. The force A acts upon the spring in much the same manner as a weight rests upon a column. The force P acts upon the spring in much the same way as though the spring were a beam fixed into a wall or support at the spring seat. We may consider A as a direct thrust from chassis to wheels. Suppose, now, that the car mounts an obstruction in the

Low Camber Gives Better Riding

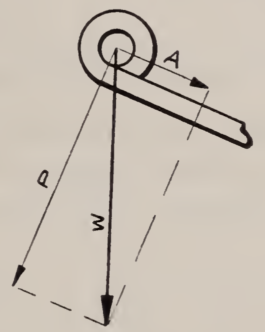


FIG. 21.

road, thus suddenly increasing W. A and P would of course increase in proportion. A, acting along the spring, would be transmitted directly from wheels to chassis as an impact or blow. P, on the other hand, although also increased, would only tend to bend the spring. The increase in P would be stored up momentarily in the spring as potential energy, to be relieved or exhausted gradually by oscillation or bouncing of the car. It will evidently be to our interest to keep A as low as possible if good riding is to be expected. To keep A small the spring should be kept flat, so that all the weight carried acts perpendicular to it. It is easily seen that the greater the height of a spring, the greater will be its curvature and the greater will be its tendency to act as a column connecting wheel to chassis.

A moment's reflection will also show that a high spring will require a longer master leaf than a low spring of the same center length. Not only that leaf, but the short leaf, and consequently, all the other leaves, require lengthening. All of which makes such a spring weigh more and cost more than a low spring of the same length. It is always more economical to raise a car by means of

High Springs Weigh More

properly constructed brackets rather than get its height by means of a high spring of great curvature.

A comparison of two springs of the same length and differing widely in height will readily show that the low spring has the better appearance.

Before being able to judge of the riding qualities of a spring we must know what relation exists between any load we place upon it and the deflection produced by that load. This relation is expressed by the ratio of load to deflection, which is known as the "pounds per inch" of the spring. It may well be called its "stiffness," as the value of the ratio increases as the spring becomes stiffer. Thus, if a spring loses 2″ in height under a load of 600 pounds, its "pounds per inch" or "stiffness" will be 600 divided by 2, or 300.

"Pounds Per Inch" Stiffness

We have already seen, in Part VI, that a spring increases in length as a load is applied. And as a long spring is less stiff than a short spring it follows that the "pounds per inch" of a spring will not be absolutely uniform, under all deflections. The same spring will show a greater stiffness when tested with 2″ deflection than if tested under a deflection of 4″. The difference between any two such readings is, however, so small as to be neglected in practice.

Relation Between the Various Heights Obtained from the "Pounds Per Inch"

Knowing the stiffness of a spring, we can readily determine how high it will stand under various loads. Thus: a spring is to carry 800 pounds, shows a stiffness of 400 pounds per inch and is 6″ high on the floor. How high will it stand when loaded? The travel of the spring will be 800 divided by 400, or 2″; it will go down 2″ under the load. Subtracting 2 from 6 we have 4″ as the loaded height.

Or, conversely: A spring is to stand 5″ high with a load of 900 pounds and shows a stiffness of 300 pounds per inch. How high should it be when free? Its travel will be 900 divided by 300, or 3″, and its height free will have to be 5″ plus 3″, or 8″.

On the European continent the relation between load and deflection is stated by noting how many inches a spring will de-

Flexibility or Deflection Per Unit Load

flect for each 100 pounds of load. This ratio of deflection divided by load, is the inverse or reciprocal of the stiffness and is known as the "flexibility" of the spring. Thus, if a spring deflects 2″ with 800 pounds its flexibility will be 2 divided by 8, or .250″ per 100 pounds. To find its stiffness we need only get the reciprocal of the flexibility and multiply it by 100. Thus, 1/.25 x 100 = 400 pounds per inch. Note that the flexibility multiplied by the load, expressed in hundred pound units, gives the deflection of the spring.

A word again in connection with writing specifications.

A Specification Which Cannot Be Interpreted

We find now and then that a builder will state the load on each spring when the car is empty and then give the number of passengers. Such information is not sufficient. The load of the passengers may be distributed between the front and rear springs in various ways and the spring builder is, therefore, still in the dark unless he is told how much passenger load comes on each spring.

Free Height, Together With Stiffness, Not Sufficient

Other builders will give the free height of the spring together with its stiffness in pounds per inch. Theoretically such information is sufficient, as it should be possible by means of it to duplicate a spring. Practically, we would advise giving, in addition, the load and the height at which the load is to be carried. This latter test is more positive. The free height can then vary slightly with no harmful results to the hanging of the car; it being the spring maker's aim to carry the given load at the proper point.

Arbitrary Test Loads Should Not Be Given. They Give No Indica-

A few builders are giving an arbitrary test load which is different from the actual load carried, the actual load in service not being known. Such information is sufficient to make a spring carry the car at the same height as some sample previously tried out. Yet the practice cannot be recommended, being open to two serious objections. The first of these is the fact that the spring maker *cannot judge as to whether the spring will ride*

tion of Riding Qualities

well. He judges riding qualities by the deflection of the spring under the actual weight of the loaded car, and as in this case he does not know the weight carried in service, he does not know the deflection in service. The riding qualities are consequently in the hands of the builder writing the specifications.

Arbitrary Test Loads Do Not Permit Knowing Stress

The second objection lies in the fact that the information does not permit the spring maker to calculate the stresses which exist in the spring, and he, therefore, *does not know whether the spring will stand up in service.* Stress is calculated from deflection, deflection is measured by the load carried. As the load carried is not known it follows that the stresses are also not known. After considering the two objections just given we believe it will be appreciated that it is always more desirable to *make the test load identical with the load actually carried in service.*

Insufficient clearance and Its Effect

The importance of having a sufficient amount of clearance should always be borne in mind. If clearance is small the frame will strike the axles. To overcome striking, the spring must, in such cases, be made stiffer. Such stiffening makes the car ride "harder" and naturally increases the weight and cost of the spring. Lack of clearance, therefore, forces the builder to use a spring of inferior riding qualities at an increase in price. Clearance may very easily be cut down by improper use of rubber bumpers.

Bumpers

Bumpers are perfectly legitimate, their function being to stop such excessive deflections as would injure the springs, but aside from such use they should be placed with the greatest care. They can so readily defeat the best efforts of the designer of the suspension.

We repeat that the amount of clearance is a very useful item of information to the spring designer. It should be stated as the amount which the body can travel beyond its loaded height.

PART X

Sheldon Axle Company's Spring Test and Data Sheets

Their Interpretation and Use.

Under this heading we give a few typical test sheets, issued by the Spring Engineering Department to consumers at the time of shipment of new samples, or when revising springs.

The test data sheets are a complete summarized statement, analysis, and report of the spring. When once an interpretation of these sheets has been made and understood, they will be found of extreme value to engineering departments in specifying future requirements, or keeping record of changes.

When sample springs have been tried out and found satisfactory, the test sheet offers a ready method of specifying duplicate orders, in a manner that is at once sure and precise:—thus, simply give date of test sheet and Sheldon Order Number, which appears at the very top of sheet. If any slight changes are desired it is only necessary to specify the required changes, for instance, height reduction, increase length, etc., and give the number of the test sheet to which the indicated changes apply.

Test data sheets are issued after each revision, change, or modification of a customer's springs, hence they form a comprehensive chronological record of all changes, as well as an engineer's and manufacturer's specification.

Attention is here directed to the fact that in giving details on these sheets a certain fixed order of statement is always followed. Thus: first, the material of which the springs are made is given, after which the following sequence is observed: width of steel, number of plates, length at the customer's specified camber, free height, size and location of center bolt or bead, grading of steel, size and character of eyes, style and shape of spring. At this point other details are accounted for which are not constant for all springs; these are: the method of alignment, type and number and location of rebound clips, length of short plate, off-center distance (eccentration) of center-bolt hole, drop; also, in springs composed of more than one element, the length of links and length of flat top as in three-quarter elliptic scroll springs, and then follows additional description peculiar to the given spring. Next in order of statement is specified the load for which the spring has been designed (there are some few exceptions), and the height which the spring shows under this load, and last is given the stiffness of the spring.

Specification No. 1

(SEMI-ELLIPTIC.)

Smith Auto Company; Washington, Mo.
Smith Order No. 1234, 4/30/12.
Sheldon Order No. 23456.

Model K, 5 Passenger Tourer, E. S. M.

FRONT.

$2\frac{1}{4}$″ x 7 x 40″ at $3\frac{5}{8}$″ out x $5\frac{7}{8}$″ out.
5/16″ CB 2″ off center,
9/32—9/32—$\frac{1}{4}$—$\frac{1}{4}$—7/32—7/32—7/32 steel,
9/16″ B. B., true sweep, clip 3rd spec. & tube, slot & bead.
Short plate 16″, 13/16″ off center, 1″ drop long end.
Tests at $3\frac{5}{8}$″ out 730 lbs. 315 lbs. per inch.

EXPLANATION OF TERMS:

$2\frac{1}{4}$″—the width in inches.

7 —the number of plates.

40″ at $3\frac{5}{8}$″ out—the length in inches center to center of eyes, when the spring has a camber of $3\frac{5}{8}$″ outside measurement.

$5\frac{7}{8}$″ out—the free height outside measurement, see Figure 1.

5/16″ CB 2″ off center—indicates that the plates are held together by a 5/16″ center bolt which is 2″ off center, making the distance from one eye to center bolt 18″ and from the other eye to center bolt 22″.

9/32—9/32—$\frac{1}{4}$—$\frac{1}{4}$—7/32—7/32—7/32—the thickness or grading of the plates from main plate to short plate.

9/16″ B. B.—meaning that the eye is lined with a bronze bush to take a 9/16″ bolt.

True sweep or T. S.—the shape and style of the spring. The initials "T. S." not only give the shape of the spring, but in this case are synonymous with "semi-elliptic spring." If this spring had had a double sweep shape, D. S. would have appeared at this point.

Clip 3rd spec. & tube.—shows that on the 3rd plate (the main plate being number one) a special or bolted rebound clip has been placed, and that it is equipped with a tube or spacer slipped over the bolt. This clip naturally holds together the main plate, long plate and 3rd plate.

Slot & Bead—the method of alignment.

Short plate 16″, 13/16″ off center—the length of short plate and the amount it is eccentrated.

1″ drop L. E.—indicates that the eye on the long end is 1″ lower than the eye on the short end, when the spring seat is horizontal.

Test at $3\frac{5}{8}$″ out 730 lbs.—is the load which the spring supports when compressed to $3\frac{5}{8}$″ outside measurement; this is the load and height at which the spring has been tested.

315 lbs. per 1″—the stiffness of the spring, it is the average load required to deflect the spring 1″.

The letters E. S. M. indicate that the above springs were manufactured from Sheldon Electric Silico Manganese Steel.

Specification No. 2

(Three-Quarter Scroll Elliptic.)

Smith Auto Company; Washington, Mo.

Smith Order No. 357, 5/7/12

Sheldon Order No. 25431.

Model J, 7 Passenger Tourer, E. S. M.

Rear.

$2\frac{1}{2}$″ x 5/7 x 55″ at $9\frac{3}{4}$″ in to out x $7\frac{7}{8}$″ out Bot., $11\frac{1}{4}$″ out Top.

5/16″ CB $3\frac{1}{2}$″ off center,

11/32—5/16—5/16—5/16—5/16—9/32—$\frac{1}{4}$ Steel Bot.

$\frac{3}{8}$—5/16—5/16—5/16—$\frac{1}{4}$ steel top. $\frac{1}{2}$″ Bush R. E., $\frac{5}{8}$″ Bush F. E. L. E., clip 3rd Rear & tube, 2nd and 4th F. E. and tube, Slot and Bead bottom, saw and bead top, 2″ links, 6″ flat top, length scroll 19″ plus 3″, travel scroll $1\frac{7}{8}$″, travel bottom $3\frac{7}{8}$″.

Test at $9\frac{3}{4}$″ in to out 985 lbs., 200 lbs. per 1″.

Explanation of Terms:

$2\frac{1}{2}$″—Width of spring.

5/7—Indicates that this is a spring composed of two elements, the upper portion having 5 and the lower 7 leaves.

55″ at $9\frac{3}{4}$″ in to out—the length of the spring measured on the bottom half, when the combined spring stands at $9\frac{3}{4}$″ in to out (see page 46.)

$7\frac{7}{8}$″ out Bot.—the free height of the bottom or lower half, outside measurement.

$11\frac{1}{4}$″ out Top—the free height of the top or upper half; in this case the scroll portion, also measured outside.

(See Figure 1 for method of measuring, also the Glossary.)

5/16″ CB $3\frac{1}{2}$″ off center—the size and location of the center bolt in the lower half, as explained in Spec. No. 1. The size of the center bolt in the upper half is not given separately, unless it differs from the bolt in the lower half. The position of the center bolt in the upper half is indicated farther on in the test sheet, where it states "length of scroll 19″ plus 3″", meaning that the distance from a perpendicular passed through the center of the scroll eye to the upper center bolt, is 19″ and from that center bolt to the front, or plain, end of the upper half is 3″.

11/32—5/16—5/16 etc. Bot.
$\frac{3}{8}$—5/16 etc. top. } —the thickness or grading of the steel, bottom and top respectively.

$\frac{1}{2}$″ bush R. E.—the size of bolt for which the eye is bushed, both top and bottom, at the rear or scroll end.

$\frac{5}{8}$″ bush F. E. L. E.—indicates that the front eye of the lower half is bushed for a $\frac{5}{8}$″ bolt. L. E. shows that this is also the long end of the spring.

Clip 3rd Rear & tube—shows that a bolted rebound clip equipped with a tube or spacer has been attached to the 3rd plate, top and bottom, at the rear end.

2nd & 4th F. E. & tube—shows the number, kind and position of rebound clips attached to the front end of the lower half.

Slot & Bead bottom—The method of alignment used on the lower element.

Saw & Bead top—the method of alignment on the upper element. (See page 10 for description.)

2″ links—naturally means that the two elements have been assembled with 2″ links.

6″ flat top—the distance from the clamped, or front, end of the upper half along which it is kept flat to form the seat. This element is then curved or arched from the flat portion to the scroll.

Length scroll 19″ plus 3″—has been explained above under the topic "5/16 CB etc."

Travel scroll $1\frac{7}{8}''$ } —the deflection of the upper and lower
Travel bottom $3\frac{7}{8}''$ } elements respectively, under the test load of 985 lbs., when the spring is properly assembled.

Test at $9\frac{3}{4}''$ in to out 985 lbs.—The load and height at which the assembled spring is tested.

200 lbs. per 1″—The stiffness of the combined spring. The explanation given in Specification No. 1 on the subject of test and stiffness applies to the above as well.

Specification No. 3

(Full Scroll Elliptic.)

Smith Auto Company; Washington, Mo.
Smith Order No. 1425, 5/12/12.
Sheldon Order No. 19877.

Model F, 5 Passenger Speedster, Dragon.

Rear.

$1\frac{3}{4}''$ x 6 x 38″ at $10\frac{1}{2}''$ out x 8″ out Top, $6\frac{1}{4}''$ out Bot. x 5/16 CB.
1-2-2-2-3-3—$\frac{1}{2}''$ bush, Full scroll, lip 4, Clip 3rd, $1\frac{3}{4}$ links, S. P. 16″.
Test at $10\frac{1}{2}''$ out 700 lbs. 175 lbs. per 1″.

$1\frac{3}{4}''$—Width of spring.

6—Number of plates. The number of plates top and bottom is the same on full elliptic springs; therefore one figure gives the number top and bottom. Compare this with Specification No. 2.

$38''$ at $10\frac{1}{2}''$ out—the length of the spring measured from center to center of eyes on the lower half, when the spring stands at $10\frac{1}{2}''$ outside measurement. In exceptional cases only, the upper half is slightly longer than the lower.

$8''$ out Top $6\frac{1}{4}''$ out Bot.—free height of the upper and lower elements respectively.

1-2-2-2-3-3—The thickness or grading of the steel. This is the same in both elements.

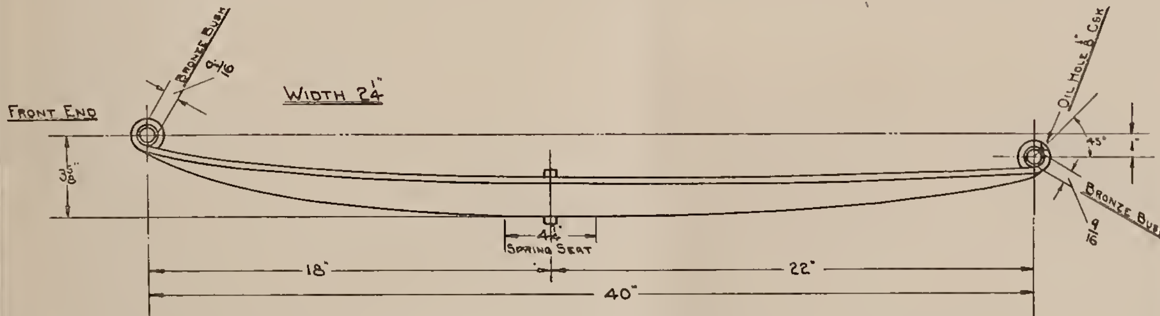
Full scroll—Type of spring. (See Model Specifications, Drawing Number 105.)

Lip 4—Method of alignment. In this case four plates are lipped top and bottom.

Clip 3rd—shows that each end of each element is equipped with a rebound clip on its third leaf. As the words "special" and "tube" are omitted, this is a regular, or clinch, clip.

$1\frac{3}{4}''$ links—See Specification No. 2. This being a full scroll spring, links are used at both ends.

The explanation covering the balance of this specification is the same as in Specifications 1 and 2.



SPRING TO HAVE THE GIVEN LENGTHS AND HEIGHTS WHEN CARRYING LOAD OF 730 LBS.

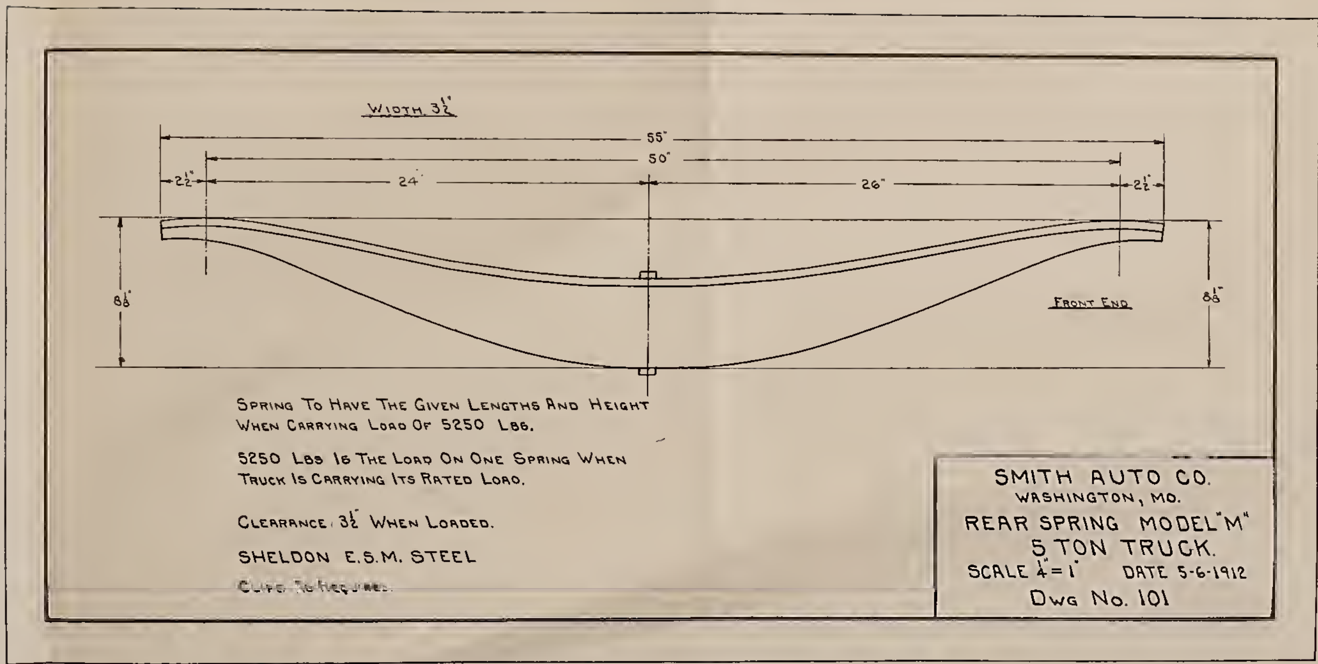
730 LBS IS THE LOAD ON ONE SPRING WHEN CAR IS CARRYING RATED NUMBER OF PASSENGERS.

CLEARANCE 4" WHEN LOADED

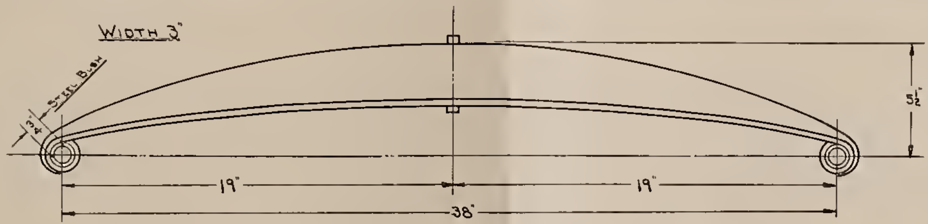
SHELDON E.S.M. STEEL.

CLIPS AS REQUIRED.

SMITH AUTO CO.
WASHINGTON, MO.
FRONT SPRING MODEL "K"
5 PASS. TOURER
SCALE ¼" = 1" DATE 4-25-1912
DWG. NO. 100



Width 3½"
55"
50"
2½"
24"
26"
2½"
8⅛"
Front End
8⅛"
Spring To Have The Given Lengths And Height
When Carrying Load Of 5250 Lbs.
5250 Lbs Is The Load On One Spring When
Truck Is Carrying Its Rated Load.
Clearance 3½" When Loaded.
SHELDON E.S.M. STEEL
SMITH AUTO CO.
WASHINGTON, MO.
REAR SPRING MODEL "M"
5 TON TRUCK.
SCALE ¼" = 1"
DATE 5-6-1912
Dwg No. 101

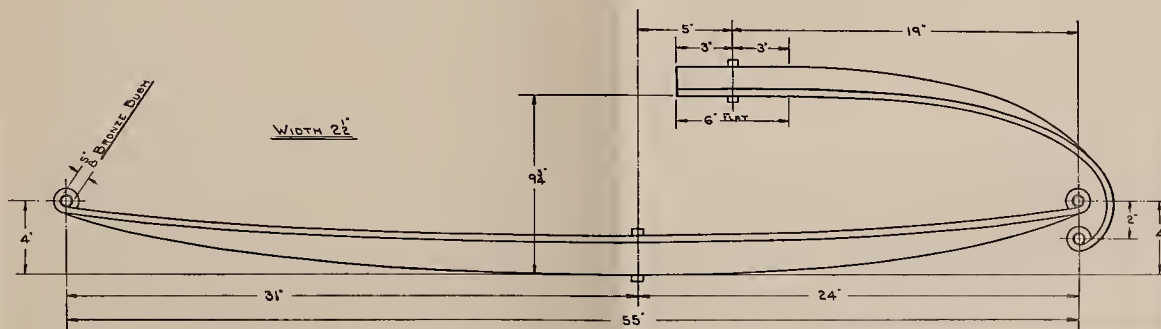


TO OPERATE IN CONNECTION WITH REAR SIDE SPRING
SHOWN ON DRAWING NO. 115

SPRING TO HAVE THE GIVEN LENGTHS AND HEIGHTS
WHEN CAR IS CARRYING RATED LOAD

CLEVIS SHACKLES 6" C. TO C. TO BE INCLUDED

SMITH AUTO CO
WASHINGTON, MO.
CROSS SPRING MODEL "D"
2 TON TRUCK
SCALE ¼" = 1"   DATE 4-30-1912
DWG NO. 102



SPRING TO HAVE THE GIVEN LENGTHS AND HEIGHTS WHEN CARRYING LOAD OF 985 LBS.

985 LBS IS THE LOAD ON ONE SPRING WHEN CAR IS CARRYING RATED NUMBER OF PASSENGERS.

CLEARANCE 8". CLIPS AS REQUIRED.

SHELDON E.S.M. STEEL

CAR IS DRIVEN THROUGH FRONT END OF SPRING

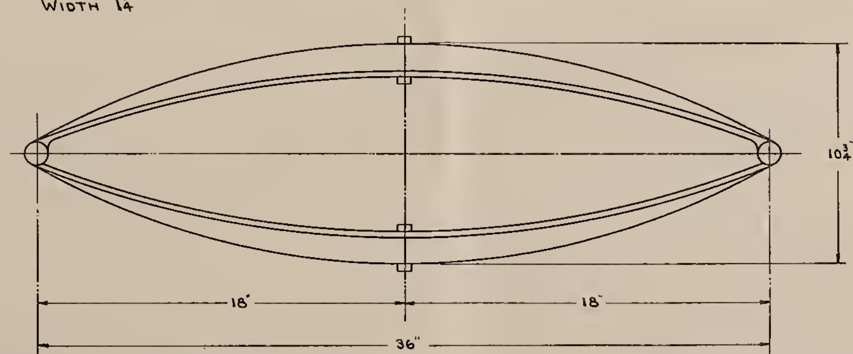
SMITH AUTO CO.
WASHINGTON, MO.

REAR SPRING MODEL "J"
7 PASS. TOURER

SCALE ¼" = 1 DATE 5-2-1912

DWG NO. 103

Width 1¾"



Spring To Have The Given Lengths And Heights
When Carrying Load Of 1075 Lbs.

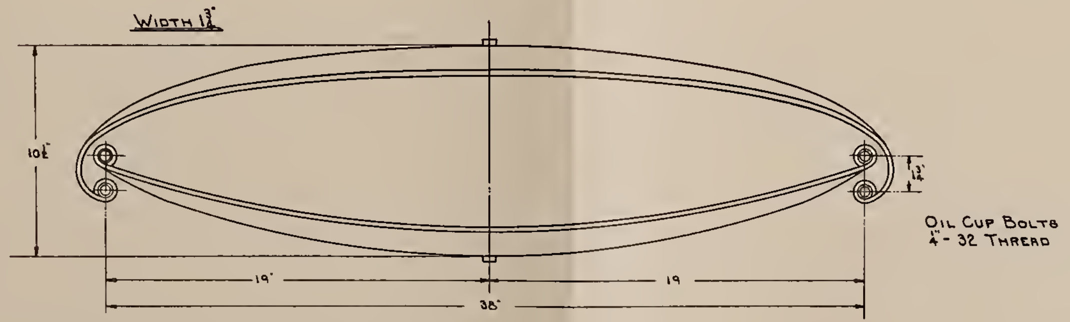
1075 Lbs Is The Load On One Spring When
Car Is Carrying Rated Load.

Clearance 7" When Loaded.

Sheldon E.S.M. Steel.

Clips As Required.

SMITH AUTO CO.
WASHINGTON, MO.
REAR SPRING MODEL "R"
LIGHT DELIVERY WAGON
SCALE ¼" = 1" DATE 5-6-1912
Dwg No. 104



To Have The Length And Height Given When Carrying Load Of 700 Lbs.

700 Pounds Is The Load On One Spring When Car Is Carrying Rated Number Of Passengers

Clearance When Loaded 7½"

Clips As Required

SHELDON DRAGON BRAND STEEL.

SMITH AUTO CO.
WASHINGTON, MO.
REAR SPRING MODEL "F"
SPEEDSTER
SCALE ¼" = 1" DATE 5-18-1912
Dwg No. 105

"The Philosopher may be delighted with the extent of his views, the Artificer with the readiness of his hands, but let the one remember that without mechanical performance, refined speculation is an empty dream, and the other, that without theoretical reasoning, dexterity is little more than brute instinct."—*S. Johnson.*

PART XI

The Sheldon Axle Co.'s Spring Plants and Organization

A narration of the rise and growth of an indigenous industry—especially if such a one be the most extensive of its kind in existence—may be profitable reading, but greater interest would be found in a personal visit to such a place.

We regret that every reader of the preceding pages cannot enjoy the privilege of a visit to the Sheldon Axle Company's Spring Plants—for it is indeed a privilege—so that to these we must bring home, through mere word description, that which they will miss. Our other reason for such a description being that the knowledge in this form may be more frequently available and to a greater number.

It is just over a quarter century ago that the men who founded the Sheldon Axle Company, selected the present site and began operations. Their intrepid belief in the undertaking is amply attested by the results obtained. The present management has been directing its policies during the past twelve years, and it is due to their precepts and ideals that the most intensive growth has taken place. Historically, this is, perhaps, as much as may interest the reader.

The management of the spring plants is in the hands of two groups of men; the one whose aims are production and handling of men and materials, and synchronizing one with the other; the second class is the engineering organization, whose work is to improve materials, methods, and to set the results of engineering investigation as the ideal to be approached by the mill. In few industries are the engineering and production heads in such close contact as here. Practice and theory have been made to coalesce to the advantage of both.

Our description of the plants and equipment may, at times, appear inadequate, and may be criticized accordingly; this is not due to a willingness to evade description or processes, but rather to the regard we have for the reader, whom we do not wish to tire by statements of small detail.

The Sheldon Axle Company's spring plants are situated in the city of Wilkes-Barre, in the State of Pennsylvania, occupying a total of fourteen acres, comprising manufacturing, experimental, shipping, office, testing laboratories and power buildings. The combined daily production of these plants is over three thousand springs, varying in weight from twelve pounds to three hundred pounds each. It requires from sixty to seventy-five tons of steel to furnish the raw material for a day's work of these plants. The transporting of such amounts of materials must needs be of a carefully planned arrangement, properly executed and working with dispatch and ease. An inspection of the half tone, showing a panoramic view of the plants, enables one to appreciate the above statement. The number of men employed is over twelve hundred. The best makers and largest producers of automobiles in this country receive their allotments from this source each working day in the year.

Raw materials, both steel and fuel, are near at hand. There never has been a delay for want of either. Ample storage room insures against delinquency or miscalculation in this respect. The steel pits carrying the rolled bar stock contain over four million pounds, representing over one hundred and fifty sizes of spring widths and thicknesses. The handling of heavy materials, such as steel, naturally requires special appliances. Two overhead cranes take the raw material from the freight cars, deposit it in the pits, from where it is further distributed to each operator by the same means.

In a plate spring each plate is a unit requiring, perhaps, different material, or a different process for its manufacture. A survey of the operations required in making a spring will give a better idea of the various stages needed to complete the whole element. Let us follow the receipt of your order.

The Filing Department receives, dates, indexes and passes it on to the Manager of the Spring Department. You are informed, at this stage, of its receipt. The Engineering Department, beginning with the Designing Engineer, calculate the various elements needed to make up the product. A copy of the design sheet is given to the Order Department, who make up the Mill Sheets, and these are passed to the Production Department.

Owing to the intricate nature of the processes in the Production Department, only a brief description can be given by elimination of those that seem of lesser importance.

The first step in the production is the shearing or cutting of the individual plates to predetermined lengths set by the Designing Engineers. From this stage the sheared plates go to the Forging Department, where a manifold number of operations begin to change the otherwise simple shapes. Here we have the punching, slotting, beading and sawing; also the tapering, pointing, swedging, trimming and eye bending. Each operation is performed by a special machine, and after each operation the plate is gauged and inspected. The half tones herewith give some idea of the multiplicity of operations and machines needed to produce these results. There is no guess work in any of these processes, nor in those following, they having all been predetermined by the Engineering Department; indeed, this is true of all the Sheldon Axle Company's Mill processes.

The next step brings the plates to the Fitter's Bench. Here the plates are given their proper shape and set, and receive the first of the many processes that are called by the general term of heat treatment. This is the critical stage and a very serious one. Recording and indicating pyrometers, together with a complete semaphore system for indicating temperature, are used throughout the production departments. An inspecting engineer attached to the engineers' staff of the Metallurgical and Chemical Department continually watches the process during heat treatment. At this stage approximate tests are made for load carrying capacity and shape and reported to the Designing Department.

Next follow tempering and annealing processes, and toughness tests of the finished spring. A battery of endurance testing machines test springs to destruction. This test is relied upon to give the most definite answers to the question of the efficacy of all the processes of making the spring. When these steps are all completed, the spring is ground, finished, assembled, marked, and given a final test, then transferred to the Shipping Department.

One point has so far been omitted in the description of the plants and organization. We feel that this should be stated in this closing paragraph. One factor is common to all departments, for which reason Sheldon springs have become famous. The aesthetic element, so often criticised as being absent in our American merchandise, must pervade in the finished goods. The artistic feature must be made a living issue of each spring. It is not considered "good enough," though all tests have been passed—it must possess distinction—it must bear all the handmarks of the masters of spring making.

PART XII

Glossary of Terms used in the Automobile Leaf Spring Industry

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Alinement-Alignment. The means of keeping the leaves of a spring from moving transversely. This is accomplished in one of several ways, notably, by use of lips on side of each plate, by ribs, slot and bead, saw and bead and partly by rebound clips or beetle rivets. The last method is not common.

Alloy Steel. Any steel which owes its properties chiefly to the presence of an element, or several elements, other than carbon.

Amplitude. The arc traversed by an oscillating body.

Anneal. Heating a piece of steel to a low red heat and cooling it slowly. This reheating also relieves stresses in the metal, and breaks up the coarse structure and brittleness.

Anti-fatigue. A term applied to a material, as steel, which will withstand a large number of applications of load without destruction. Such steel is said to possess great *Dynamic Resistance.* The term is comparative.

Applied Load. The application of a load, continuously, or in steps, but without releasing of such load at any time during the test; dimensions measured under these conditions are known as "applied load test" dimensions.

Arch. A distance measured on a semi-elliptic spring from a line drawn through the center of the spring eyes to the top of the master leaf, or to the bottom of the short plate. The height of the arc from the chord. The term *Set* has been used in an analogous way to indicate the distance measured to the *Top* of the master leaf. This term (*Set*) is now used, however, to express a distance measured between successive plates of a spring when they are free and not bolted or clamped, but with their points just contacting each neighboring plate.

Synonyms—Camber, compass, height, opening, in dimension, out dimension.

The *Opening* of a spring and the *In Dimension* refer to the height of a semi-elliptic, measured from a line drawn through the spring eyes to the top of the master leaf.
The *Out Dimension* is the height measured from a line passing through the center of spring eyes to the outside of the short plate on the spring.

Auxiliary Spring. A separate spring, although sometimes combined with the regular spring, and so disposed as to come into action automatically when a certain predetermined load has caused the main springs to deflect. The auxiliary springs may be either of the plate, or coil type. They may also be composed of a single leaf, a plurality of leaves or, more commonly, of a semi-elliptic spring having plain ends; they are frequently used on heavy vehicles. When such springs are used to prevent large deflections of the main springs of heavy vehicles, they are called *Bumper Springs.*

Synonyms—Buffer springs, jack springs, helper springs, check springs, overload springs, supplementary springs. The last term has recently come into use, being more frequently applied to a coil or spiral spring designed to act with and increase the deflection of the total suspension.

Back. The main plate or longest plate of a spring, which most frequently has its ends turned over on itself, making the eyes.

Synonyms—Master leaf, main plate.

Band. A ribbon of steel, usually from $\frac{3}{8}''$ to $\frac{1}{2}''$ thick, formed into a hollow box section, having the ends welded. It is shrunk on the spring to keep the plates together and forms a flat seat for the spring; only used on very heavy springs. The portion of the band which rests on the spring seat is called the *Butt,* or *Head* of the band, while the upper is called the *Strap* of the band.

Barrel-Shackle or (Shackel). A swiveling, or universalling type of shackle, used to connect the transverse spring to the side springs of a three-quarter platform suspension; also used to connect any two springs lying at 90° to each other and in different planes.

Bead. An indentation in the leaf of a spring which raises a portion of the metal on one side and depresses it on the other. The successive beads usually "nest" in one another and are used in place of the center bolt to prevent transverse motion of the spring and the separate leaves relative to the axle; also used in saw and bead construction for alignment.

Synonyms—Nib, teat, projections, dowels, depressions.

Beetle Rivets. A special form of rivet used to rigidly connect the master leaf and long plate, in a transverse direction, but free to slide in a longitudinal one.

Berlin Head. A head forged on or welded to the end of the master leaf in such a manner that a line drawn though the center of the head passes through and coincides with the center thickness of the master leaf. See Figure 15.
Synonym—English head.

Berlin Eye. An eye of a spring plate so formed that a line passing though the center of thickness of the master leaf passes through the center of the eye. See Figure 6.

Black-Finish. When the more flocculent scale is removed by any one of several methods, there still remains a darkened oxidized surface on the plates, hence the term. Heavy springs are usually finished in this manner.

Body Springs. A term used to describe the long semi-elliptic springs extending from front to rear axle and supporting the body and mechanism. The term is now used by some in a more general sense to describe the plate springs used to suspend the chassis, hence they are sometimes also called *Chassis Springs.*

Synonym—Side springs.

Bolt. The word is seldom used alone, but is compounded with such terms as: *Center,* meaning that such bolts are used to clamp the leaves together; *End,* when used in the eye of the spring; *Shackle,* when placed through shackle and eyes; *Eye, Spring, Oil Cup, Grease Cup, Self-lubricating.* The last terms are applied to a shackle, or eye, bolt having a grease cup and cap at one end to feed either grease or other lubricant to the spring bushings.

Bolted Rebound Clip. A clip, bolted and riveted to a spring and used to prevent the plates from parting with each other when the load is suddenly removed from the spring; for example, as in a violent rebound. The clips are, usually, riveted to one plate and their free ends are connected by a bolt and nut. When a tube of brass or steel is placed over the bolt in a manner so as to act as a spacer to prevent the clip stock from pinching the sides of the plates this tube is specified by adding to the above term "and tube." See Figure 14.

Box Eye. An eye formed on the end of a plate spring producing an opening which is substantially rectangular in shape. *Synonyms*—Loop end, box end.

Box Clip. A U shaped piece of steel having its free ends threaded; used to clamp the spring to its seat; usually made of very low carbon steel, but should be made of nickel steel.

Synonyms—Saddle clips, spring clip, seat clip.

Bright-Finish. When spring plates are ground so as to leave the surface bright and without scale.

Buffer Spring. (See Auxiliary.) The term buffer is also distorted sometimes to the word "bumper." The word bumper when used alone refers to a rubber cushioning device used to prevent the striking of such adjacent parts as frame and axles.

Bushing. A hollow cylinder of metal made of steel or bronze and used to line the eye of a spring to prevent wear on the bolt and eye.
Synonyms—Sleeve, tube, lining.

Butt End. See Band.

Butt of Spring. The thickest portion of the spring; the central portion of a spring where the leaves have not been thinned down by tapering or drawing.

Button Head. A head forged on the end of the master leaf and circular in section. The upper surface of the master leaf is tangent to the outer portion of the head. See Figure 15.

Camber. See Arch.

Cantilever Spring. Another name for a quarter elliptic spring. When the thickest portion or butt is fixed to a bracket it is called a *Fixed Cantilever Spring;* when the spring is a semi-elliptic spring and so arranged that the center, or butt portion, is allowed to swing on the frame or a bracket on the car and one end is shackled or otherwise attached to the frame while the free end is on the axle, then the spring is called a *Floating Cantilever Spring.* When one end of a spring has a scroll end, but in other respects complies with the general description of the floating cantilever spring it is then called a *Floating Cantilever Scroll Spring.*

Capacity. The number of pounds required to deflect a spring, or combination of springs, one inch.

Synonyms—Stiffness, scale.

The word capacity had been used to indicate the total load a spring, or system of springs, can carry safely without taking a set. In this sense it is but rarely used in the automobile spring industry. In the railroad leaf spring industry the term capacity is used to designate the load the springs are designed to carry.

Cee Spring. Used in England to denote a scroll spring. The name C spring is still used in the horse-drawn vehicle spring industry to describe a large multiple plate scroll closely resembling the letter "C." The true C spring has been used by some foreign automobile makers for town car suspensions and electric pleasure vehicles.

Centre Bolt. A bolt used to clamp the leaves of a spring at the butt of the spring.

Check Spring. See Auxiliary.

Clearance. The vertical height between the two most adjacent members in a car when loaded which are liable to strike each other. A dimension effecting the design of springs with reference to their flexibility and deflection.

Colloquialism—Jam space.

Clevis Shackle. A link which is approximately U shaped and so arranged that a pin or bolt can be placed through the free ends connecting the spring thereto. The lower end of the shackle is attached to the vehicle by means of another bolt. A *Loose Clevis Shackle,* or universal shackle, is used on large three-quarter platform springs to join the sides and transverse member.

Clip Rivet. A rivet used to firmly connect the rebound clips to the tapered end of the plates.

Compass. See Arch.

Concave Steel. The cross section of spring plate steel is not rectangular, but is slightly concave at the middle; the section is rolled concave, hence the name. In the earlier days of the spring industry the plates were made concave by hammering and this operation of concaving the steel was called "middling," and the steel was said to have been "middled."

Constant. A dimension in a three-quarter elliptic spring measured from the center of the front end eye of the lower half elliptic to the under portion of the master leaf of the quarter elliptic. A term applied by Mr. William H. Tuthill.

Cross Spring. The semi-elliptic spring of a platform suspension which connects the rear ends of the side springs.

Curvature. A term applied to the shape of a spring and describing its approach to circular shape.

Dead. When any two or more leaves of a spring placed together and not clamped are found to contact along their entire length they are said to be dead. (See Nip.)

Dead Load. A load resting on a spring which does not change with time or use. The weight of the body, chassis and equipment produce the dead load resting on the springs.

Synonym—Static Load.

Deflection. The distance a given point on a spring moves away from another and fixed point on same; usually, the perpendicular distance traversed by a point in the center of the eye relative to a fixed point at the top of the master leaf. A displacement of one part with reference to another. A distortion.

Synonyms—Travel, Bending.

Dimension. Specific lengths, widths and thickness or heights of a spring.

Distortion. Generally applied to the effect produced by the unintentional displacement of the plane of plate, as, for example, in the heat treatment of spring steel, when the plates may warp. Unintentional deflection produced by extraneous forces.

Double Scroll. When a scroll is formed at each end of a plate as in a double scroll full elliptic spring. A *French Double Scroll* is a full elliptic having a single scroll on each spring element.

Double Sweep. A reversal of curvature in a spring, usually near the ends or eyes. Contra-curvature. See Figure 2.

Synonyms—Reverse Sweep, Reverse Curvature, Double Compass (English).

Dowels. Sometimes applied to a beaded leaf. (More recent usage.) A doweled spring is one whose short plate is so designed that it has a pin or dowel riveted through a hole made for the purpose and into which doweled and countersunk head the next beaded plate is inserted.

Draw. The operation of tapering the leaves of a spring to produce points.

Synonyms—Taper, Scarf, Point.

When used with reference to heat treatments the word draw is synonymous with *Tempering* or *Drawing Down*.

Drawn Eye. An eye of a plate spring the leaf of which before being rolled into an eye has been tapered. This is sometimes resorted to in order to maintain an overall diameter to a specified dimension.

Drilled Eye. An eye of a spring whose internal diameter has been finished by drilling to specified size.

Drop. The vertical distance which one end of a spring is lower than the other. Front springs generally have a drop.

Ear. A term used, though not extensively, to describe the eye of a spring.

Egg Shape. Applied to describe the shape of the points of leaves.

Elastic. The property possessed by most materials of returning to their original form after they have been subjected to a deformation.

Elastic Limit. When a load is applied to a substance a deformation, or strain, results; within certain limits, the resulting strain is directly proportional to the stress; the point at which this proportionality ceases is called the elastic limit. When the elastic limit is exceeded the material does not return to its original dimension and is said to have taken a permanent set.

Elastic Elongation. The elongation of a material, within the elastic limit, due to stresses operating within that limit. For good steels the elastic elongation may go as high as 75/10,000 of their length. (See Modulus of Elasticity).

Elastic Shackle. A term more commonly used by French writers, applying to any highly flexible medium interposed between two elements of a spring and taking the place of the rigid links or shackles.

Synonym—Supplementary Springs.

Element. In chemistry, used to denote a material which cannot be reduced to a simpler form—such as Gold, Silver, Carbon, Silicon, etc. In spring manufacture it is applied to a portion of a spring system which is in itself a completed unit; thus, a three-quarter elliptic spring contains two elements composing the spring, the semi-elliptic element and the quarter-elliptic element. In a three-quarter platform we have three elements, the two side elements, and the transverse, or cross element.

Elliptic. A term applied to a spring having the general shape of an ellipse. The word elliptic refers in general to a full elliptic spring. The modifications are usually designated as follows: *Full Elliptic, Semi-Elliptic* or *Half Elliptic,* etc.

Scroll Elliptic. An elliptic spring having a scroll at one end, this may be a three-quarter or a full elliptic type, single or double scroll type, quarter elliptic, or any other variety to suit specific cases.

End. The eye or other portion most remote from the center or butt of the spring. When the end having the eye is referred to it is designated as the eye end; also, when a spring is offset or eccentrated we have two ends, known as *long end* and *short end* or, when referring to their relation with reference to the car, or vehicle, we speak of them as *front end* and *rear end.* The eye end is sometimes spoken of as the *pin end;* this term is becoming obsolete in the automobile spring industry. When the end of a spring is flat and has no eye or, is very slightly curved, the curvature being reversed from the general direction of curvature of the main plate, the end is then called a *plain end.* If the reverse curvature is very pronounced and has no eye it is called a *curved plain end;* and when, as is sometimes the case, the eye of a spring may be drilled and tapped for a grease cup, it is called the *tapped end.* When the master leaf is rolled so as to leave a substantially rectangular opening or eye, it is called a *loop end* or *box end.* The leaves may, for one reason or other, be tapered at the end; we then have a *tapered end.* There are other designations for ends, but they are so numerous and but little used that they are left out of consideration here.

Endurance. Applied in the usual lay sense to materials that withstand considerable use before destruction.

English Eye. See Berlin Eye.

Eccentrate. Eccentric, not central. A spring whose center bolt, or butt center, is not in the geometric center of length of the spring; this term is best suited to describe this condition and we urgently request its use instead of the present *Synonyms*—Offset, Out of Center.

Eyes. An annular hole in the master leaf of a spring made by rolling the leaf back on itself. A pin or shackle bolt is used to connect the spring through the eye to its attached member on the car.

The eye of a spring may be turned *"up"* or *"down"* or it may partake of the nature of both and is then called a *"Berlin" Eye,* or an *"English" Eye.*

When eyes are finished by having a bushing inserted, we have a *"Bushed" Eye. Reamed, Drilled, Solid, Welded* are explanatory of each type.

When the outermost portion of the spring eye is "finished" to an "exact" width we have a *"Milled" Eye.* Then we have a *Swedged, Wrapped, Forged, Rolled* and *Taper Rolled Eye.*

Fillister Head. Refers to shape of the head of the center bolt clamping the spring leaves.

Finish. Used in conjunction with other words describing the surface or method used to clean the plates of flocculent scale. Thus we have, *Bright Finish, Half Bright, Black, Grindstone, Polished Top, Buff,* etc.

Flash. Many spring makers to-day and, especially those of old, practised a method of annealing the spring plates by inserting them in an oven and waiting until their greasy surface became hot enough to flash off the oil hence, the term applies to an ancient practice which has been superseded by pyrometers and more exact methods. "Flashed Springs" are still too common.

Flat Top. The portion of a quarter elliptic spring element whose length is flat to permit of its being clamped to a flat seat or bracket. The amount of flat top (length) is of great importance to the spring designer and the car constructor. Should be specified on drawings.

Flexibility. The deflection of a spring in inches per 100 pound load placed at its "center." For quarter elliptic springs it is the deflection in inches per 50 pounds placed at the eye end of the element. In three-quarter platform springs the flexibility is the deflection, in inches per 200 pounds, placed on the entire system.

Floating Cantilever. See Cantilever.

Floating Upper Elliptic. Another term for a floating cantilever spring when used in conjunction with a semi-elliptic element at the bottom.

Floating Upper Scroll Elliptic. The same as a floating upper elliptic, except that one end has a scroll.

Forged Eyes. See Eyes.

Fracture. A noun used to designate the broken ends of a piece of material. The physical aspects of a fracture are usually stated thus: Crystalline, Granular, Radial, etc.

French Points. See Text for photograph.

Front End. See End.

Grading. Making the thicknesses of steel used in a spring element variable. The more graded the spring the better, but there are limits.

Grasshopper. A term nearly obsolete, used to describe a semi-elliptic spring.

Grindstone Finish. A colloquialism used by a few spring manufacturers. (See Finish.)

Half Bright. The "finish" of the spring leaves. (See Finish.)

Half Elliptic. See Elliptic.

Hanger. A misnomer for shackle—more often used to describe the brackets or appliances used to connect the shackle with chassis.

Head. The head of a spring is usually a wrought iron forging having a variety of shapes which are forged, or welded, to the master leaf. (See Berlin Head, etc.)

Heat Treatment. A process, or several processes, of subjecting the materials used in making springs to definite temperatures or, otherwise acting on these materials through heating and cooling to refine and improve their strength and endurance; essentially, a careful and precise heating and cooling process subject to many alterations that endows any given material with the best dynamic properties. The older spring makers knew little of the scientific aspects of heat treatment.

Height. See Camber, Arch, etc.

Helical Spring. A helical spring is one which is wound on a cylindrical surface and the separate turns advance like the thread of a screw. These springs may be made of either square, round, rectangular or, indeed, any special section of bar.

Helper. See Auxiliary.

In to Out (Dimension). The upper surface of the master leaf is known as the inner and the lower surface of the short plate is known as the outer surface of a spring. In a three-quarter elliptic, where the master leaf in the quarter element is set on a perch, or pad, and the half elliptic has its short plate on a perch it is essential that the combined heights of springs be given "from pad to pad." This gives the "in to out" dimension of the spring. It is never used as descriptive of a dimension of a single spring, but always applies to a combination of elementary portions. (See Text.)

In Dimension. See Camber or Height. The height measured vertically from center of eyes (or from the end of plain end spring) to top of master leaf.

Inertia. The inherent property possessed by a substance of resisting change of state. That is, if at rest, it tends to continue at rest and when in motion it tends to a continuation of this state, unless other forces compel alteration of this state.

Isochronous. To swing over different lengths of arcs in equal times; to travel over unequal lengths in equal times.

Jack Spring. See Auxiliary. The term Jack without the apellation (of the term spring) was used formerly to describe a small windlass, or apparatus, used to change the height of a body on horse-drawn vehicles.

Jam Space. A colloquialism meaning the same as Clearance, which see.

Laminated. In the early history of the carriage and railroad spring industry the springs were always designated as Laminated Springs; the term is still used in place of leaf. It has no other meaning than that of ordinary usage which designates a thin plate or sheet.

Lap. The distance that one plate in a spring extends over another plate at either end; it is the length of this extension.

Lapped End. When the end of a leaf, usually the master leaf, is sharply bent back on itself to form a bearing surface, it is then called a *Lapped End.* In England it is called a *Slape End.*

Leaf Spring. A spring composed of a plurality of thin sections of material in the form of narrow and comparatively long plates, or sheets, usually of steel.

Leaves. The separate plates comprising a leaf spring.

Left Hand Spring. A spring placed on the left hand side of a vehicle; this may be either front or rear and is so designated.

Length. The length of a spring is understood to be the projected length measured between the centers of the eyes of the spring; in a semi-elliptic spring it is the chord of the arc; this is sometimes also called the *Projected Length.* The actual length of the arc is called the *developed length* or, in shop parlance, owing to it being a length that the plates must be cut to, it is known as the *cutting length.* The cutting length is the actual length of the plates.

Life. A rather indefinite term used to describe the longevity of springs when doing work; the capability of exercising its natural functions. See Anti-fatigue and Endurance.

Lip. A projection on the edges of the leaf, made by forging, or drawing out the metal and then turning it up at right angles to the plate width. Used to prevent relative transverse motion of the plates.

Synonym—Lug. (Used instead of the word lip by English spring makers.)

Live Load. The actual load to be transferred by the vehicle aside from its own weight, as passengers, cargo, merchandise, etc. The load producing deflection in an endurance spring testing machine.

Synonyms—Paying Load, (In case of Commercial Vehicle). Passenger Load, in luxury or passenger vehicles.

Load. The weight carried by a spring.

Long Plate. The plate next to the master leaf in a leaf spring.

Long End. In an eccentrated spring the longer "half" measured from the center of the center bolt, or center of butt, to the center of the eye of the corresponding end.

Loose Shackle. A shackle made of two links and not integral with each other—sometimes, (though not properly) called a loose link shackle.

Loop End. A box eye on end of spring. See Box Eye.

Main Plate. The longest plate of a spring; the back, usually having eyes rolled, or forged, at its ends and through which the effort or load is applied to the spring.
Synonyms—Master Leaf, Back.

Manganese. A chemical element found in all spring steels.

Master Leaf. See Main Plate, Back.

Middled. A term formerly applied by English spring makers to substantially rectangular sections of steel which are slightly concave at the middle of the section.

Middling. The process of concaving spring steel by hammering it to concave shape. A term now nearly obsolete.

Modulus of Elasticity. Applied to desigante the force that would be needed to stretch, or elongate, a material, if such were possible, to double its original length; a coefficient of stiffness. Thus: if a piece of steel were, say, ten inches long and one inch square in section, it would require a force of 28,000,000 pounds to stretch it to a length of twenty inches. It is true that no piece of steel can withstand such a prodigious force but, the fact is interesting nevertheless and the knowledge of this is of great importance in the realm of mechanics. This value of 28,-

000,000 seems to be nearly constant for all spring steels and is, generally speaking, independent of their chemical composition.

Moment of Inertia. When applied to a plate of rectangular shape, as spring steel, it is a mathematical expression of its width, multiplied by the thickness cubed, and the result divided by twelve. It is the measure of the body to resist forces acting thereon and is independent of the nature of the substance.

Moment of Elasticity. The product of the moment of inertia by the modulus of elasticity; it represents the actual opposing, or resisting, force that a given material presents to change of shape within the elastic limit of the material.

Net Weight. The actual weight supported by a spring not including its own weight.

Neutral Axis. An imaginary axis through the center thickness of a plate where no tension or compression exists; it is an axis of shear. It is also the center of gravity of the section.

Nib. See Bead.

Nip. A term used, more particularly in England, to indicate the height between any two adjacent plates of a spring when the leaves are not clamped together but the points of each successive plate touch the preceding one. When any two successive plates have no nip they are said to be "dead." *Synonyms*—Set, Pinch, Pull.

Offset. Not central, out of center, eccentrated.

Open Head. A head, or forging, welded to the end of the main leaf in such a way that, the upper face of the leaf is on a line tangent with the top of the head; it is distinguished from a button head by the absence of the circular boss which is the conspicuous portion of a button head. In an open head the stock between the ears extends to the point only on the outside circumference of the eye nearest the center of the spring.

Closed Open Head. This head is the same as an open head, except that the stock between the ears extends to the end of the head.

Oval Head. The shape of a special bolt head used in the eyes of some full elliptic springs, which join the two elements together.

Overall. A dimension applied usually to the outside heights of full elliptic, three-quarter elliptic springs, and to the overall length of a spring measured to the outside portion of the eyes.

Peening. An act of striking plates with a round headed hammer to straighten them. A practice that should be deprecated.

Perch. An expression formerly used for a separate bracket which the spring rested on, but now applied to the pad of the axle to which the spring is rigidly attached.
Synonyms—Seat, Pad.

Perch Filler. A piece of canvas steeped in linseed oil and white lead and placed on the perch to fill out the inequalities and permitting the spring to be firmly attached to an otherwise uneven surface; probably first suggested by R. D. Woodford.

Pin Head. A round pin attached to the master leaf by forging it solid, having its long axis parallel and usually in line with the center length of master leaf, which enables the end of this to go into a hole in the axle. This method of attachment prevents torsional stress on the main plate.

Plain End. The end of the master leaf is in some springs left without an eye and such ends are frequently straight or flat, although, in some instances, this end is given a slight reverse sweep.

Plate. A single leaf of a spring. Depending on their location, size, or function; the various plates are named: *Long Plate, Master Plate, Master Leaf, Short Plate, Rebound Plate, Auxiliary Plate,* etc.

Platform. A combination of four semi-elliptic springs, arranged so that two are on the sides and two are across the vehicle; also, any other combination, similarly disposed, with relation to the vehicle. When combinations, other than semi-elliptics, are used they receive special names of the type of spring to which they belong and the word platform is prefixed; three-quarter platform, etc.

Points. The end of the spring leaves. These are forged or drawn into special shapes and receive names accordingly. Thus we have *Round, Oval, Egg shape, French, Square,* etc.

Polished Top. A style of finish in which the upper surfaces of the leaves (those visible to the eye when the spring is in place) are ground upon a grindstone and afterward polished upon a buffing wheel.

Pressure Block. A piece of metal or wood, shaped approximately to fit four to five inches of the short plate of the spring and used as a spring seat when applying a load in testing springs for their carrying capacities, etc.

Pumping. The act of loading and unloading a spring rapidly to loosen up scale or to "nest" the plates.

Pull. See Nip.

Radial Elliptic. A special arrangement of a full elliptic spring in which the lower half elliptic is longer and sometimes wider than the upper; one end of the upper element is attached by a bolt or shackle to the lower and the other end is attached by means of a shackle to an extra plate lying over the master leaf of the longer spring.

Rapping. The act of jarring, shaking or tapping a spring, so as to release the friction of the plates, thereby enabling the effects of friction to be noticed (or removed) in testing.

Rear Spring. Any spring used on the rear end of a vehicle.

Rebound Clip. A "U" shaped piece of steel rigidly attached to one plate and surrounding two or more plates and preventing their parting in the event of strong rebound, or, on the rapid removal of the load from a leaf spring. There are a variety of forms of rebound clips used.

Rebound Plate. A plate placed over the master leaf of a spring and so shaped that it carries a load only when the direction is, in sense, opposed to that of the main spring. This plate may be as long as the main plate, but is usually much shorter. Its utility in the respect mentioned is doubtful, but it possesses other features that are thought desirable.

Released Load. The various dimensions of a spring can be ascertained by applying given loads, in steps, and measuring successively their alteration; also a much greater load may be applied and by slowly releasing, in steps, the various dimensions can be obtained. The two methods do not give the same results, but the last method is sometimes used and is called the Released Load Method. When used in conjunction with the applied load method it enables us to ascertain the frictional work of the spring.

Rib. A long and narrow grooved projection thrown up by forcing out metal at the center of leaf point or end, and used to align plates.

Ribbed Spring. A spring whose plates are provided with ribs to align the plates.

Riding Quality. An indefinite term expressing a general but vague meaning referring to the softness of a suspension.

Right Hand. Referring to a spring placed on the right side of a vehicle. (See Left Hand.)

Round Head Rivet. A type of rivet having a round head and used to fasten the rebound clips to leaf points.

Rolled. The process of making steel plates, or leaves, or the points thereon by being passed through rollers. Also descriptive of making the eye of a spring.

Round Point. The shape of the end of a leaf on a spring. No precise description can be given to cover this term. (See Text.)

Saddle Clip. Sometimes, but incorrectly, applied to the rebound clip, but more frequently and appropriately applied to the box clip used to hold the spring to its seat.

Synonym—Box Clip.

Saw and Bead. A means of keeping the plates in alignment. A bead or projection is stamped on one plate and made to fit into a sawed slot in the adjacent plate.

Scale. This term is synonymous with the word capacity, which see.

Scarfing. The process of tapering plates to weld on eyes; the process of making points on plate ends.

Scragging. A term used by English spring makers to describe a bending test on steel for springs or, a deflection test of a spring.

Scroll End. The end of a spring turned or bent around a form giving it a large curve, which is called a scroll. Sometimes called a "C" end, owing to the slight resemblance to this letter. The term "C spring" is applied by some to a scroll end, but this is incorrect.

Seat. A pad or bracket on which the spring rests.
Synonyms—Perch, Chair, Pad, Spring Rest.

Self-lubricating Bolt. A bolt containing a reservoir for grease or oil; the lubricant flows through proper channels to the spring eye, or bushing, and, of necessity, lubricates both bolt and bushing automatically.

Self-lubricating Bushing. A bushing containing graphite fillers, which are supposed to perform the office of automatically lubricating both bushing and bolt.

Self-lubricating Shackle. A shackle so designed as to contain a well or reservoir, together with a proper arrangement of wicks to feed oil to the shackle bolts and spring eyes. Such are the F. J. M. or Miesse Shackles.

Semi-elliptic. A half elliptic spring or, a spring having a shape which is approximately a half of an ellipse.

Set. Meaning the arch or camber of a spring or a plate; in this sense the term is not often used. The distance or "nip" in respective plates when free and unbolted or unbanded and the points of each leaf just contacting with the one above it; a deformation or distortion which has become permanent, as in a piece of steel which has been stressed beyond its elastic limit. The set is then said to be permanent.

Shackle or Shackel. A clevis or a "U" shaped piece of material used to join a spring to its hangers.

Shape. Refers to the form or the contour of a spring when either free or loaded; also, the kind of points on a leaf.

Shock Absorbing. The capacity of a spring to yield to sudden blows and prevent their reaching the vehicle. Something that prevents rapid or large changes in acceleration by being interposed between the substance tending to undergo changes of acceleration and the force producing it.

Short Plate. The shortest plate in a leaf spring forming a unit with the series carrying the main load.

Side Spring. Any spring used on a vehicle and placed parallel to the vehicle length. Formerly this term applied to a long semi-elliptic spring extending from the front axle to the rear axle and called a *Body Spring.*

Silicon. A chemical element.

Slape End. A spring end having its master leaf folded back on itself for a distance of about 2″ to 5″ and forming a pad, or shoe, to slide on a casting provided for the purpose on the frame of the vehicle.

Sleeve. A bushing usually of metal. A tube. The term bushing is preferred.

Soft Spring. A term used to designate a spring having a high flexibility. It bears no relation to the quality of steel, for all steels are equally "soft" or "hard." See Modulus of Elasticity.

Spacer Clip Plate. A plate placed on the master leaf of the spring and used as a distance piece for the box clips.

Special Bead. A nib or projection in a plate made in accordance with some "special" design, the size of the bead not being a "standard" carried in stock.

Special Bolt. The term is clearly indicative.

Special Bolt Head. This is clearly indicative.

Specification. A concise and detailed description in writing, or a drawing showing the requirements of the purchaser. (See Text.)

Spiral Spring. A spiral spring is one which is wound around a fixed center and continually recedes from it like the hair spring of a watch; such springs have been recently used in conjunction with plate or leaf springs, both in this country and abroad.

Spoon End. An end on a spring (seldom used now) having a concave seat in which a swiveling member fits.

Spring Hanger (or Horn). A bracket-like piece, permanently attached to the frame by rivets or, other fastening and to which the springs are attached by shackles.

Spring Bracket. Used for the same general purpose as a spring horn.

Spring Leaf Retainer. A longer term, meaning the same as a rebound clip. Probably called retainer for it, doubtless partly functions in the same way as a lip or slot and bead, saw and bead, etc.

Spring Stop. A rubber bumper that prevents the spring contacting with frame or other adjacent members.

Static Load. The load on a spring which does not alter, as frame, body, etc.

Stiffness. The number of pounds required to deflect a spring, or a combination of spring elements made into a unit, one inch.

Synonyms—Capacity, Scale.

Strain. The stretch or elongation caused by a force or load acting on a piece of material. Every stress is accompanied by a strain. Hence, without a stress there can be no strain. Strains produced by forces acting within the material are known as internal strains.

Stress. That which produces a strain. A force.

Stubbs Gauge. A gauge for measuring thickness used in the spring industry. (See Text.)

Supple. Pliable, yielding, flexible.

Supplementary Spring. An extra spring of any kind, although generally of the helical variety, connected with the plate spring and used to increase the total deflection of the spring system; sometimes used in the sense of auxiliary, helper, or jack springs. The application of this term is, for the present, at least, not precise and care should be exercised in its application; it is, indeed, used in two distinct and almost opposite senses.

Snubbing. The process of rolling whereby the thickness of the steel is reduced at a given location only. This distinguishes Snubbing from Taper Rolling, in which the thickness uniformly decreases throughout the length of the portion rolled.

Swedged. The operation of compressing a piece of a plate to contract it, as by rolling or otherwise working it.

Sweep. The radius of the curve to which a spring plate is shaped; a curved line; also means the arch, or camber, or compass. *True Sweep*, generated by being drawn from a single center. *Double Sweep; Reversed Sweep*, two curves drawn from opposite and even different centers, producing contra-flexure shapes. Also called *Double Compass*. *Varying Sweep*, having two or more loci for generating curves.

Synchronism. To be in phase with, to coincide with.

Taper. To thin down as by rolling, drawing or forging.

Teat. A nib or projection on a leaf of a specific size.

Teeter. A colloquialism, meaning to rock like a see-saw, more especially used to describe a transverse rolling or rocking, as is common in a three-quarter platform suspension using a flexible cross spring, or, where a stiffer spring is used and a high center of gravity maintained.

Synonym—Rolling. Rolling or teetering is noticeable where the side springs are narrow or where lateral stability is wanting.

Temper. To harden a piece of steel by heating to a high temperature, then quenching in a cold medium, as water, oil, etc.

Tensile Strength. The force, measured in pound units, required to disrupt a piece of material by being stretched or pulled apart. Tensile Strength is becoming to be understood as the force in pounds required to pull apart one square inch of material.

Tensioning. A term formerly applied to the act of putting a nip in plates by peening them. A practice rapidly becoming obsolete.

Test Height. The opening, camber, or in to out dimension of a spring when under a given test load.

Tobin Bronze. A material often used for bushings in spring eyes and consisting substantially of 58.2% copper, 2.3% tin and 39.5% zinc.

Transverse Spring. A spring, usually of the semi-elliptic type, placed at right angles to the car length or parallel to the car width, and not used in conjunction with any other spring.

Treatment of Steel. Usually applied to abbreviate the term heat treatment, which see.

Torsional Strain. A strain produced by twisting, as the strain produced in a shaft transmitting power. Should be avoided in springs. Torsional strains are sometimes produced in three-quarter elliptic springs when the upper and lower elements are not parallel.

Synonym—Twisting strain.

True Sweep. See Sweep.

Tube Spacer. A brass or, sometimes, a steel tube used to space the rebound clips so that they do not bind or pinch the plates.

Twisting Strain. See Torsion.

Uniform Strength. A spring so proportioned that the stress is everywhere the same; hence, it is of uniform strength.

Universal Shackle. A shackle or, a combination of two shackles, allowing freedom of motion in two planes.

Underslung Spring. A spring fastened underneath the axle instead of on the top of same.

Vanadium Steel. A steel alloyed with the element vanadium. Also applied to a steel in which vanadium may have been used during its manufacture to divest it of objectional substances.

Warping. To twist out of intended shape, to distort, as by heating or rapid cooling.

Weight Capacity. The maximum weight a spring will carry without permanent set.

Wrapper. A leaf rolled over the outer portion of the spring eye.

Wrought Shackle. A shackle made by a forging process from wrought iron.

Yield Point. In testing the strength of materials that point, at which, the rate of stretch suddenly increases rapidly. It is nearly, but not quite exactly, coincident with the "elastic limit." Practically the elastic limit is taken as the yield point.

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